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KOREA 2023

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OECD Reviews of Innovation Policy: Korea 2023

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Foreword

The *OECD Review of Innovation Policy for Korea 2023* is the 34th in a series of OECD Country Reviews of Innovation Policy (https://www.oecd.org/sti/inno/oecd-reviews-of-innovation-policy) and the third one that covers Korea (following the OECD Reviews of Innovation Policy: Korea 2009 and the OECD Reviews of Innovation Policy: Industry and Technology Policies in Korea [2014]). This review was requested by the Ministry of Science and ICT (MSIT) and the Science and Technology Policy Institute (STEPI).

Societies and economies are undergoing significant transitions and challenges, such as digital transformation, the green transition, demographic change, growing geopolitical divides as well as the global COVID-19 pandemic. All of these have highlighted both vulnerabilities and strengths of the Korean economic model and national innovation system and have underscored the need for continuous policy attention. While Korea is commonly considered an innovation leader in some digital technologies, which also contributed to its widely recognised pandemic response at the onset of the COVID-19 crisis, these emerging technologies also hold significant disruptive potential for the more traditional manufacturing industries. Furthermore, the growing geopolitical divides have particularly exposed some of the vulnerabilities of Korean embeddedness in global value chains. In addition, the green transition and population ageing will significantly shape Korean industry and society at large. In order to prepare for the structural change brought about by these challenges, STI policy should assume a leading role. This review presents a comprehensive analysis of how Korea can leverage its world-leading potential in STI to achieve resilience amidst societal challenges and solidify its position as a global innovation leader.

This review lays out an analysis of the key elements, dynamics and processes which characterise the Korean national innovation system and, as such, provides a comparative assessment and recommendations drawing on experiences and good practices from OECD and non-OECD countries. The findings also serve as a thorough knowledge base for the Korean government to support the implementation of its 5th S&T Basic Plan. The comprehensive review is relevant to a wide array of stakeholders ranging from government officials, researchers, and entrepreneurs to the general public in Korea, other OECD countries and beyond as the transitions are global in nature, and the assessment, as well as identified solutions, may be applicable in other contexts.

The review was led and managed by Alan Paic, Senior Policy Analyst at the Science and Technology Policy (STP) Division at the OECD. The main authors of the review were Alan Paic, Philippe Larrue, Mario Cervantes, Wanho Song, Christian Biesmans and Bora Kim (Directorate for Science, Technology and Innovation, OECD). The review draws on an extensive background report prepared by Byeognwon Park, Jungwon Lee, Hyeok Lee, Hyeonchae Yang, UngKyu Han, Kwangho Lee, Eunjung Shin, Soojung Sohn, Sunwoo Kim, Yongsuk Jang, Myonghwa Lee, Seunghyun Kim, SeoIn Baek, Mijung Um and Inkyoung Sunof of the Science and Technology Policy Institute (STEPI). The analysis benefited from invaluable inputs provided by Erik Arnold (consultant to the OECD; Senior Partner of the Technopolis Group and an Honorary Professor at the University of Manchester) and Sylvia Schwaag Serger (consultant to the OECD; Professor at Lund University), particularly to Chapters 1, 2 and 4. Martin Hemmert (consultant to the OECD; Professor at Korea University) contributed in particular to Chapters 1, 3 and 4. All consultants provided extensive analytical, research and drafting support. Within the OECD Science, Technology and Innovation directorate, the report received valuable contributions from Blandine Serve and Kei Kato, particularly statistical analytical support, Seoyeon Kim, who provided research support to Chapters 4 and 5 and Beatrice Jeffries, who continuously offered administrative support. Sebastian Ordelheide and Sylvain Fraccola facilitated the communication and publication processes of the review. Julie Harris (external editor) provided immaculate professional editing services for the report.

The project team is grateful to the Ministry of Science and ICT (MSIT) and STEPI for requesting this review and for their continuous support during the process, in particular to Dayeon Jung (Deputy Director at the Science and Technology Division of the MSIT), Suhyun Park and Jisun Jang (former and acting Deputy Director at the Multilateral Cooperation Division of the MSIT, respectively). Byeongwon Park and Yongsuk Jang (Senior Research Fellows at STEPI) supported the review team with extensive organisational, research and statistical support and their participation in the fact-finding interviews involving close to 100 stakeholders from business, academia and government. The project team would like to particularly extend its gratitude to the interviewees of the virtual mission in September 2021 and the hybrid mission in October 2021, who represented a wide range of different stakeholders and perspectives and significantly helped the project team gain in-depth insights into the Korean national innovation system.

The review benefited from invaluable inputs and guidance provided by Andrew Wyckoff (Director of the OECD Science, Technology and Innovation (STI) Directorate), Jens Lundsgaard (Deputy Director of the STI Directorate), Dirk Pilat (former Deputy Director) as well as Alessandra Colecchia, Head of the Scientific and Technological Policy Division in the STI Directorate. The review has furthermore received feedback as part of the presentation of its draft overall assessment and recommendations (Chapter 1) at the Working Party on Technology and Innovation Policy (TIP) meeting on 30 May 2022, which included a peer review session with valuable inputs provided by Amélie Clément, Rebecca Leinen and Lennart Stenberg. The final version of Chapter 1 was presented at the Committee for Science and Technological Policy (CSTP) meeting on 21 March 2023, and the TIP meeting on 8 December 2022 specifically discussed Chapter 4 of the review. The Secretariat is grateful for comments and feedback received by the MSIT and the Ministry of Education throughout the process, as well as from other OECD directorates, including the Economics Department, the Education and Skills Directorate and the Centre for Entrepreneurship, SME, Regions and Cities.

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Abbreviations and acronyms

AI	Artificial intelligence
ASEAN	Association of Southeast Asian Nations
BERD	Business expenditure on research and development
DARPA	US Defense Advanced Research Projects Agency
DND	Digital New Deal
ECI	Economic Complexity Index
ETRI	Electronics and Telecommunications Research Institute
EU	European Union
EUR	Euro
FDI	Foreign direct investment
FIR	Foreign input reliance
FMR	Foreign market reliance
FTE	Full-time equivalent
FVA	Foreign value-added
GDP	Gross domestic product
GERD	Gross expenditure on research and development
GHG	Greenhouse gas
GII	Global import intensity
GND	Green New Deal
GOVERD	Government expenditure on research and development
GRI	Government research institute
GVC	Global value chain
HEI	Higher education institution
HERD	Higher education expenditure on research and development
HHI	Herfindahl-Hirschman Index
HRHR	High-risk, high-reward
ICT	Information and communications technology
IEA	International Energy Agency
IP	Intellectual property
IPO	Initial public offering
KAIST	Korea Advanced Institute of Science & Technology
KARPA	Korea Advanced Research Programme Accelerator
KEI	Korea Environment Institute
KISTEP	Korea Institute of S&T Evaluation and Planning
KND	Korean New Deal
KRW	Korean won
M&A	Mergers and acquisitions
MFP	Multifactor Productivity
MNC	Multinational corporations
MOIP	Mission-oriented innovation policy

MOTIE	Ministry of Trade, Industry and Energy
MSIT	Ministry of Science and ICT
NGO	Non-governmental organisation
NRF	National Research Foundation
NST	National Research Council for Science and Technology
ODA	Overseas development assistance
OLED	Organic light-emitting diode
PACST	Presidential Advisory Council on Science and Technology
PBS	Project-based system
PCT	Patent Cooperation Treaty
PIAAC	Programme for the International Assessment of Adult Competencies
PISA	Programme for International Student Assessment
PNP	Private non-profit
PPP	Purchasing power parity
PRI	Public research institute
R&D	Research and development
R&I	Research and innovation
R&R	Roles and responsibilities
RTA	Revealed technology advantage
RTO	Research technology organisations
S&T	Science and Technology
SDG	Sustainable Development Goals
SEK	Swedish krona
SME	Small and medium enterprise
SNU	Seoul National University
STEM	Science, technology, engineering and mathematics
STI	Science, technology and innovation
SWOT	Strengths, weaknesses, opportunities and threats
TIPS	Tech Incubator Program for Start-up
UNIST	Ulsan National Institute of Science and Technology
US	United States
USD	United States dollar

Executive summary

Key findings

The Korean success story of economic catch-up is widely recognised as a prime example of achieving socio-economic growth and development. This accomplishment was made possible by the science, technology and innovation (STI) ecosystem, which played a critical role in integrating new technology from abroad. This development has helped Korea sustain rapid progress towards the global innovation frontier with the potential to lead global markets in crucial digital technologies such as in 6G infrastructure.

Korea has some of the world's highest innovation inputs in terms of human capital and research spending. Korea has the highest share of tertiary graduates among OECD countries, many of whom are in the science, technology, engineering and mathematics (STEM) disciplines. The young are particularly adept at using digital and ICT technologies, which enables employers to integrate emerging technologies quickly. Besides human capital, financial inputs for innovation, as measured by gross domestic expenditure on R&D (GERD), ranks second worldwide with 4.93% of GDP in 2021.

The Korean society and economy must proactively address societal challenges and global transitions such as the digital transformation, population ageing and the green transition. Although Korea excels in certain digital technologies, not all firms have the necessary capacity to adopt emerging technologies, which poses risks, particularly for small and medium enterprises (SMEs) and their competitiveness. Furthermore, by 2050, Korea is projected to experience the most significant increase in its old-age population compared to its working-age population, which poses a further threat to economic growth. Among OECD countries, Korea also possesses the lowest proportion of renewable energy in relation to its total primary energy supply, which requires substantial investment, particularly in the emission-heavy energy and manufacturing sectors.

The government provides strong support to SMEs, but innovation activity is still concentrated in large firms. Seoul has emerged as one of the globally leading start-up ecosystems, thanks to significant financial and structural support that ensures ease of doing business, along with an advanced ICT infrastructure and access to public sector innovation. Nevertheless, start-ups experience challenges when trying to scale-up internationally. Support for other SMEs appears to be less effective, with low levels of innovation and the second-highest productivity gaps with large firms among OECD countries.

Productivity gains and innovative activity have largely been concentrated in specific sectors. There is a large gap in growth, productivity and R&D spending between the manufacturing sector (in particular, ICT manufacturing) and the service sector. Going forward, it is important to foster high-value-added services in particular. Despite various policy measures and successes in some areas, results have thus far fallen short of the potential, and a significant gap in growth and productivity persists between ICT and non-ICT sectors. With a high share of employment in the ICT industry, there is a risk that other sectors are falling behind, especially in the context of the digital transformation. As the young, well-educated and urban population continues to benefit from Korean leadership in the ICT and manufacturing sectors, this remains vital to prevent exacerbating inequality.

A forward-looking vision for the Korean research system will need to enhance autonomy in universities and government research institutes and foster high-risk, high-return research with long-term impact and breakthrough potential. The public administration of the research system will need to enhance long-term focus, risk tolerance, and application of the subsidiarity principle, as well as an emphasis on qualitative performance assessment, to promote high-risk, high-reward research. Significant recent efforts to do so include the National Research and Development Innovation Act. Whether these efforts have achieved their intended outcomes needs to be assessed in the future.

STI governance in Korea is based on a strong foresight system featuring ambitious mid- to long-term plans and strategies involving the whole of government, but co-ordination can be improved. There is a unique, comprehensive, and centralised multi-step process in place to determine the strategic directions for STI across the government. However, inter-ministerial co-ordination remains an important challenge and needs to be improved to help Korea tackle societal challenges through research and innovation. Overall, the existing co-ordination process appears to be overly burdensome and focused on the allocation of resources and the management of budgetary competition among ministries. Emerging problems and new priorities tend to be addressed through reallocation and reshuffling of funding rather than the development of a coherent and holistic R&I policy. The recently established challenge-led schemes and the ambitious mission-oriented policy strategy present a promising model for the future of Korean STI policy, should they be based on a systemic approach to promote continuous strategic dialogue across the government.

Key recommendations

This review has developed three main pillars with specific recommendations the Korean government can consider to prepare its STI system for a new era of innovation.

I. **Promote cross-cutting strategy and foresight**.

There is a need for a shared vision that brings together various long-term sectoral strategies to define the contribution of STI to Korean society. The STI system should be oriented to enable transitions and address societal challenges by adopting a whole-of-government approach, experimenting with mission-oriented policies, and ensuring continuity across government mandates. Furthermore, the Korean STI system needs to further internationalise through projects, researcher mobility and participation in international research infrastructures.

II. **Support business innovation**.

The role of the services sector, particularly in fostering innovation in knowledge-intensive services, needs to be amplified. Korea needs to strengthen the diffusion of innovative technologies to SMEs and bolster the global connectivity of start-ups. This could be accomplished through a range of policy initiatives, including reducing administrative burdens, developing skills, fostering co-operation with large businesses and academia, and implementing targeted support programmes.

III. **Strengthen the research system**.

To better serve Korea’s needs in the post-catch-up era and amidst global transitions, the capabilities of universities and GRIs to conduct excellent research must be strengthened. This can be achieved by promoting the autonomy of academic institutions, enhancing evaluation and assessment systems, tailoring the financing model of these institutions to align with the achievement of their objectives, promoting co-operation between GRIs and universities, and creating targeted programmes for high-risk, high-reward research.

1 Overall assessment and recommendations

This chapter presents the overall assessment and recommendations of the review. The recommendations are categorised according to the three pillars of cross-cutting, business innovation and research system and linkages recommendations. The assessment is structured following the chronological order of the review, with an initial overview of the Korean innovation system, its evolution and challenges for the future, followed by a comprehensive analysis of business sector R&D and innovation, the production, circulation and diffusion of knowledge as well as governance for a new era of innovation in Korea.

1.1. Recommendations

This section introduces the overall assessment and recommendations (OAR) of the *OECD Reviews of Innovation Policy: Korea 2023*. The second section presents an overview of Korea's innovation system, guiding the reader through its evolution to the opportunities and challenges it may face in the future. The following sections capture these characteristics in greater detail by innovation actors, starting from the third section on business innovation; the fourth section on the production, circulation and diffusion of innovation; and the fifth section on Korea's science, technology and innovation (STI) governance structure. The final section provides an overview and summary of Korea's innovation system's strengths, weaknesses, opportunities and threats (SWOT).

This review's OAR show that Korea is on its way to becoming an innovation leader and needs to continue to build on its current strengths, such as its leadership position in manufacturing industries, a highly educated workforce and excellent information and communications technology (ICT) infrastructure. Korea's research and development (R&D) spending as a share of gross domestic product (GDP) is among the highest in the world at 4.9% of GDP in 2021. The recommendations presented here suggest rebalancing spending towards areas that require attention, such as fostering a mission-oriented approach and disruptive innovation. Korea needs to address several imbalances and faces a number of innovation-related challenges for sustainability in the years ahead, including climate and ageing. The OAR introduces recommendations that respond to these challenges by:

- creating a shared vision for Korean society (Recommendation 1)
- directing STI systems to enable transitions and address societal challenges (Recommendation 2)
- improving the efficiency of R&D policy implementation and evaluation (Recommendation 3)
- fostering internationalisation of STI (Recommendation 4)
- strengthening the role of the service industry (Recommendation 6)
- strengthening the diffusion of innovative technologies (Recommendation 7)
- further developing linkages between universities and businesses (Recommendation 11).

The 11 recommendations are grouped into 3 pillars. While all recommendations are important, they are listed roughly in the order of importance, starting from the overall vision, the need to redirect the STI system towards societal challenges and the need for efficient policy implementation:

1. **The first pillar deals with cross-cutting recommendations,** including developing a shared national vision of Korea's future economic and societal development (Recommendation 1), built upon a solid foresight exercise and a broad-based consultation with all stakeholders within the innovation system. Such an exercise should demonstrate the importance of adopting additional measures to help direct STI systems towards accelerating key transitions (e.g. net-zero) and addressing societal challenges (Recommendation 2). Such strategies need to be underpinned by efficient R&D policy implementation and evaluation (Recommendation 3). Further efforts in internationalising STI will help stimulate knowledge exchanges and international opportunities (Recommendation 4). The transition will necessitate strengthening skills and behaviours in order to gain international leadership in innovation (Recommendation 5).
2. **The second pillar deals with business innovation.** The high value-added service sectors need to be further strengthened, as they can help accelerate the transition towards the knowledge economy (Recommendation 6). The uptake of new technologies by small and medium-sized enterprises (SMEs) and the global connectivity of start-ups need to be supported (Recommendation 7). Finally, rebalancing the policy mix for business innovation can help generate economic and social benefits from support to R&D and innovation (Recommendation 8).
3. **The third pillar deals more specifically with the research sector.** Universities (Recommendation 9) and government research institutes (GRIs) (Recommendation 10) will need

a set of measures to enhance knowledge production, and additional measures are needed to drive linkages between these actors and businesses (Recommendation 11).

1.1.1. Pillar 1: Cross-cutting recommendations

Recommendation 1: Create a shared national vision and long-term plan for Korea's development

Overview

Korea has experienced rapid development over the past 60 years. It has successfully caught up with some of the world's most developed nations and has created prosperity and well-being in its society.

However, these transitions have also created a number of imbalances, as have been pointed out throughout this assessment, between the older and younger generations; between the Seoul capital area as one of the world's largest and most prosperous metropoles and rural areas; between globally competitive conglomerates and much less competitive SMEs; between a world-leading manufacturing sector and a below-average service sector; between a thriving domestic start-up scene and limited internationalisation of these start-ups, to name just a few.

Korea also faces acute challenges in meeting carbon emission goals in a strongly energy-dependent economy and one of the most acute demographic challenges globally.

Above all, Korea has been striving to switch from a successful catch-up economy to a world leader for over a decade. It has reached that status in a few sectors, such as ICT manufacturing. However, overall, Korea remains a fast follower rather than a leader in key technology sectors, such as artificial intelligence (AI) or biotechnology, for example.

In order to address all these issues holistically and in the context of a longer time frame, Korea needs to enact a paradigm shift by creating stronger links between sectoral strategies. Ideally, a cross-cutting and holistic vision would accelerate society's development towards an inclusive, knowledge-based economy where STI would play a key role.

In the absence of a whole-of-government national development vision covering all areas of policy, Korea should create explicit links and co-ordination mechanisms between existing sectoral strategies:

- The Ministry of Science and ICT (MSIT) has adopted a Science and Technology Future Strategy for 2045. This remains a sectoral strategy for science and technology (S&T), which does not address innovation and is not connected to an overall economic development vision.
- An initiative was launched by the Ministry of Economy and Finance (MOEF) in June 2021 for a mid- to long-term economic and social policy roadmap. Similarly, there are no indications that this plan takes into account the role of S&T.

Detailed recommendations

- Recommendation 1.1. **Carry out a foresight exercise to create a vision linking the Science and Technology Future Strategy for 2045 and the long-term strategy of the Ministry of Economy and Finance.** A top-level expert group would be set up to include a diverse group of highly prestigious domestic and foreign experts from business, academia and other key actors, including from social sciences. It would be tasked with drawing up alternative scenarios of Korea in 2045, with respect to the structure of the economy (evolution of the balance of manufacturing vs high value-added services); inclusiveness with respect to regional development (Seoul capital area vs regions); including socially disadvantaged groups; addressing societal challenges; opening up to international co-operation; and achieving a world-leading status. Elements of both existing strategies should be considered with equal weighting, with a view to unifying the vision, particularly around the green and digital transitions, to realise synergies and focus future policy action across government towards achieving these overarching goals.

- Recommendation 1.2. **Organise a broad societal consultation on linking the Science and Technology Future Strategy for 2045 and the long-term strategy of the Ministry of Economy and Finance.** Following the publication of the results of the foresight exercise with its different scenarios, consultations could be organised at all levels, including for citizens who should be able to contribute ideas and views on the various scenarios, their desirability in terms of outcomes, the impact of various policy options and their robustness relative to the various scenarios, identifying policy choices that have the greatest likelihood of positive outcomes, as well as the pitfalls that need to be avoided.
- Recommendation 1.3. **Set up a whole-of-government steering committee to develop a shared vision for Korea's development and the role of STI in contributing to it,** built upon the key findings from the foresight and consultation exercise. In such a process, all areas of policy, such as digital policy, social policy, education, environmental and health policies, should be discussed as they interact with STI. These issues fall outside the traditional STI policy portfolios but invariably affect the effectiveness of policy makers' interventions. The shared vision should then be presented to a broad group of stakeholders for further consultation and buy-in. It is important that all stakeholder groups feel full ownership of this vision.
- Recommendation 1.4. **Draft an actionable and budgeted action plan for linking the Science and Technology Future Strategy for 2045 and the long-term strategy of the Ministry of Economy and Finance initiative, with clear responsibilities and monitoring mechanisms.** Clear intermediate objectives should be set at five-year intervals to reach the desired scenario in 2045. A more detailed action plan should be developed for the first five-year period, with assigned responsibilities, key performance indicators and a monitoring process.

Recommendation 2: Direct STI systems to enable transitions and address societal challenges

Overview

Korea's S&T enterprise has been a critical component in its economic development and its ability to avoid the middle-income trap many other countries face today. These impressive S&T resources will be equally critical in enabling Korea to handle a number of increasingly urgent societal challenges, such as an ageing population, growing polarisation (between generations, regions and income groups) and climate change. However, science and technology do not automatically or inevitably provide solutions to such problems. In fact, they can contribute to exacerbating them. A range of actions should be considered to ensure that knowledge and innovation can contribute effectively to ensuring Korea's future economic, social and environmental sustainability.

Detailed recommendations

- Recommendation 2.1. **Ensure the long-term continuity of STI orientations across different governments.** Different countries have found different ways to achieve this. One option would be to make the S&T Basic Plan a ten-year rolling plan. In order to allow the longer-term perspective needed to address ambitious and complex societal challenges while providing room for adaptation (aligned with the political cycle), the Basic Plan could become a ten-year plan revised every five years. A binding five-year investment plan with earmarked financial resources would be attached to the first five years. This would allow both: 1) continuity to address issues like climate change or ageing that cannot be tackled in a five-year government term; and 2) flexibility to accommodate new priorities or approaches by the newly elected president within the longer-term framework (e.g. very few new challenge areas or sub-areas could be added/suppressed). Another option would be to create a dedicated, national, long-term, future-oriented programme for addressing major challenges, which could be governed under a specific long-term financial arrangement with regular evaluation milestones, such as the French Future Investment Programme (PIA) or the Dutch Top Sectors Policy.

- Recommendation 2.2. **Establish a whole-of-government approach to and policy co-ordination on certain key policy priorities.** In particular, in order to achieve net-zero targets:
    - Rapidly ramp up investment in innovation for renewable energy sources, such as solar and wind energy, to reduce carbon emissions. This should include strengthening the demand for renewable energy sources (e.g. through public procurement, supportive regulation and legislation, demonstrators and test sites) and, more generally, strengthening the broad diffusion and uptake of renewable energy technologies and solutions across industries and sectors.
    - Complement government support for investment in low-carbon technologies by further improving innovation-enhancing market mechanisms, such as a carbon pricing system, which sets prices sufficiently high to effectively incentivise producers and consumers to reduce carbon emissions.
    - Strengthen public communication and education about the severity of global warming while emphasising the opportunities that low-carbon technologies represent for Korean firms and the economy more generally.
- Recommendation 2.3. **Mobilise untapped resources for tackling societal challenges.**
    - Mobilise and provide support for students, researchers, cities, citizens, municipalities and companies (including start-ups) to contribute to addressing specific societal challenges, e.g. through competitions and prizes, pledges, innovation funding, proof-of-concept funding, experimentation, etc.
    - Create experimentation spaces to test new solutions (innovation labs, including regarding public sector innovation), assess the current higher education and research institute system, structure and organisation according to its ability to contribute to strategic technological and societal innovation and transformation priorities and objectives.
    - Strengthen climate literacy in primary and secondary schools.
- Recommendation 2.4. **Support initiatives that connect and catalyse basic research from different disciplines around a specific societal challenge.** The Convergence Research and Convergence Accelerator programmes launched by the US National Science Foundation can serve as inspiration. They seek to address societal challenges and "accelerate solutions toward societal impact" by building on basic research and "integrating knowledge, methods, and expertise from different disciplines and forming novel frameworks to catalyse scientific discovery and innovation" around a specific societal problem.
- Recommendation 2.5. **Focus the role of the Innovation Office on strategic policy making in order to ensure holistic co-ordination and contribute to enhancing synergies and co-operation between programmes.** Korea's unique annual comprehensive and systematic review of all R&D programmes reduces duplications across the whole government structure and contributes to ensuring a broad consistency with the S&T Basic Plan. However, this systematic review at the central level is a resource-intensive task that tends to focus the attention and resources on programme management and compliance rather than on strategic issues. The government should consider the costs and benefits of this review process and delegate to ministries and agencies relevant tasks that could be performed at lower levels without hindering cross-government co-ordination. While centralising certain tasks is important, this recommendation applies the subsidiarity principle, where lower governance levels fill in the details of decisions made

at higher levels. This would allow the Science, Technology and Innovation Office (hereafter, the "STI Office") and the President's Advisory Council on Science and Technology (PACST) committees to focus on strategic policy making, budgeting and monitoring, as well as on national missions (see Recommendation 2.8).

- **Recommendation 2.6. Implement high-level national missions targeting large and ambitious societal challenges.**
  - A small number of pilot national missions (two to three) should be designed collectively and endorsed by PACST, chaired by the President of Korea. These missions should be included in the Basic Plan and revised or continued every five years after a thorough evaluation. The multi-year funding of each mission should be programmed in the above-mentioned five-year investment plan attached to the Basic Plan. The missions address key societal challenges facing Korean society through integrated intervention across the government structure and throughout the innovation cycle (from upstream research down to deployment). The missions are systemic in that they combine a wide range of activities (research, infrastructure, skill formation, etc.) on different types of potential technological and non-technological solutions, using a package of policy interventions (subsidies, regulatory reforms, procurements, etc.).
  - The implementation and monitoring of missions should support dedicated cross-ministerial co-ordination groups tailored to co-ordinate each mission. Furthermore, within the STI Office, dedicated operational teams should integrate the policy co-ordination, budgeting and performance evaluation for each mission. PACST could review and validate the mission strategic roadmaps and evaluation every five years and on an annual basis the monitoring reports of each mission. As part of their plan submitted to the government, the GRIs should specify their potential contribution to national missions. This initiative could also act as a "governance laboratory" for the challenge-based transformative governance framework proposed in Box 1.1.

Box 1.1. Towards a challenge-based transformative governance framework in Korea

The OECD proposes that in the coming years, Korea turns gradually towards a new "virtual architecture" for the governance of STI systems. The proposal is to structure strategic orientation and policy making along some broad challenges involving several ministerial portfolios and set up spaces for continuous cross-ministerial co-ordination around these challenges across the policy cycle. The main objective of this new type of STI governance is to set up mechanisms to allow for complex and long-term "transformative" policy issues to be collectively understood and led across the whole policy cycle, from strategic orientation to policy making and co-ordination and, finally, evaluation set to provide feedback into strategies and policies.

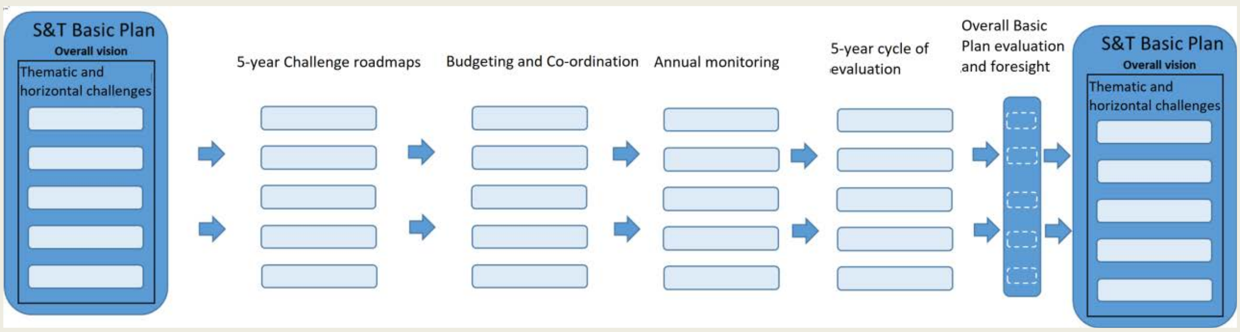
Some of these challenges would be thematic, i.e. addressing economic and societal challenges, while others would relate to the challenge of strengthening the system as a whole (e.g. improving basic science, upgrading business innovation, etc.).

These thematic challenges, set every five years in the Basic Plan, would extend far beyond R&D and aim at mobilising society as a whole and guiding research and innovation (R&I) activities (in a broad sense, i.e. including social innovation) to solve these challenges. Each challenge would have a dedicated "nested" structure of governance composed of bodies with high-level representatives of each ministry, overseeing more operational sub-committees with mid-level policy makers in charge of the relevant programmes and initiatives in different areas relevant to the challenge.

These challenges would also structure the entire policy cycle, from strategic orientation to evaluation. The process could start with the selection of the challenges as part of the Basic Plan development process.

PACST would endorse these challenges. With support from the STI Office, cross-ministerial challenge groups would develop five-year challenge roadmaps for each challenge, with associated budgets. The groups would also review activities and produce annual monitoring reports for each challenge (Figure 1.1).

Figure 1.1. The challenge-based transformative governance framework



Source: OECD based on stakeholder discussions.

- The entire STI governance structure is impact-oriented and structured around challenges with clear objectives.
- STI activities have better visibility and accountability due to the challenge-based structure (e.g. implementing challenge-based budgeting).
- There is systematic co-ordination throughout the five-year and annual policy cycles based on continuous interactions.
- The pooling of resources and strengthening of cross-ministerial co-operation supports realising the challenges' objectives.

Note: The missions proposed in Recommendation 2.6 represent a way to experiment with such a challenge-based structure, which involves the integration of policy co-ordination, budgeting and performance evaluation functions and continuous cross-government monitoring of actions and progress.

Recommendation 3: Improve the efficiency of R&D policy implementation and evaluation

Overview

Effective R&D policy evaluation is needed to flexibly adjust and achieve desired objectives. This means going beyond simple monitoring indicators and assessing the impact of policies.[1]

Detailed recommendations

- **Recommendation 3.1. Revise the methodology used in the pre-feasibility test[2] to make it better suited to the characteristics of R&D programmes**. Although the methodology of the pre-feasibility test has been adapted and a two-step process implemented, further improvements can be made to make it more suitable for risky and exploratory R&D programmes. This creates a scenario where certain crucial strategic directions hinge on the outcome of this technical process, resulting in inefficient strategies to bypass the test. Valuable insights could be gleaned from the *ex ante* evaluation of the European Commission's Research and Innovation programmes.
- **Recommendation 3.2. Inter-ministerial programmes should be implemented using joined-up approaches where different agencies work together to manage the programmes, and the**

ministries are represented in dedicated governance structures. In many cases, Korea's large inter-ministerial projects result in allocating different projects to the respective agencies of the different ministries, in contrast with agency co-operative schemes found in other countries (e.g. Pilot-E in Norway). While in some cases, a single agency is tasked with funding projects for different ministries, it remains rare and administrative silos tend to be replicated within large-scale programmes.

- Recommendation 3.3. **Set up a research and innovation assessment framework focused on impact and learning**. This framework could build on and expand the experience of the Research Excellence Framework (REF) in the United Kingdom. Such a framework would make it possible to identify good practices – and challenge areas –within the Korean STI system. It would have wider coverage than the UK REF because it would be applied to higher education institutions and GRIs (with different modalities to be adapted for these organisations). Furthermore, it would include research as well as innovation activities. Under this framework, both institutions would be required to submit "R&I impact case studies" that demonstrate the impact of their R&I activities on wider society (including national missions). These case studies would also include an auto-assessment of the bottlenecks and difficulties encountered that hindered impact delivery. The set of case studies would be analysed, and the results of the analysis would be discussed at the government level to feed into policy decisions regarding strategic (re-)orientation and needed structural reforms.

Recommendation 4: Foster the internationalisation of science, technology and innovation

Overview

The Korean innovation system needs to be better integrated into the international STI ecosystem to be stimulated by the flow of ideas and exploit international opportunities. This applies to international co-operation on a bilateral and multilateral basis, as well as the integration of foreign brainpower in the Korean ecosystem.

Detailed recommendations

- Recommendation 4.1. **Enhance scientific excellence and international co-operation through regional S&T funds.** Current discussions about Korea's association with Horizon Europe are on the right track and will open up possibilities to collaborate and compete with the best European minds. In addition, Korea could consider establishing a regional fund for innovation similar to Horizon Europe in East Asia and Southeast Asia. A research excellence fund, such as the European Research Council, should also be considered in the region. Such a fund recognises excellent research and can be a strong incentive for developing world-class scientific projects.
- Recommendation 4.2. **Envisage the development of large regional scientific infrastructures with neighbouring countries.** In the past, it has been shown that geopolitical tensions can be overcome in science. Such was the case of the European Laboratory for Particle Physics (CERN), established in the aftermath of World War II, which brought together scientists from formerly belligerent European nations to work together on peaceful nuclear research. The ultimate result was one of the world's leading scientific infrastructures, which has also benefited from significant economies of scale and allowed European countries to compete in the domain with much larger countries, such as the United States. This model was replicated at Synchrotron Light for Experimental Science and Applications in the Middle East (SESAME), which brings together scientists from Bahrain, Cyprus,[3] Egypt, Islamic Republic of Iran, Israel, Jordan, Pakistan, the Palestinian Authority, and most recently in the Southeast Europe region in the South East European International Institute for Sustainable Technologies (SEEIIST), which brings together scientists from Albania, Bulgaria, Greece and all seven units from former Yugoslavia, some of which have no diplomatic relations. A similar infrastructure in partnership with East Asian and

Southeast Asian neighbours may benefit Korea, particularly in disciplines where Korea lacks the critical mass to compete globally.

- **Recommendation 4.3. Facilitate international mobility of researchers, innovators and entrepreneurs in the public and private sectors.** In view of the demographic trend and a reduction in the supply of skilled labour domestically, Korea could do more to harness skilled immigration. Action is needed to adapt cultural attitudes towards foreigners to encourage the acceptance and integration of foreigners into Korea's traditionally homogeneous society. Regulations should ensure equivalent hiring and promotion opportunities. Voluntary classes and counselling services for foreigners that would help them integrate into Korean society could also be useful.

  A further increase in the share of English-language curricula in Korean universities would help attract more international students and help Korean students be more open to international co-workers and scientific and business partnerships.

  Researchers could also benefit from foreign talent for collaboration and mobility schemes to (temporarily) move abroad, which could spur creative thinking and knowledge transfer. Programmes enabling and fostering this kind of exchange should be at a larger scale. Consider supporting international post-doc positions, i.e. funding positions for foreign post-docs to spend time in Korea.

- **Recommendation 4.4. Increase internationalisation in recruitment, evaluation and funding allocation.** Use the opportunity presented by the increased acceptance of online meetings to involve more foreign peers in the assessment of research funding applications (e.g. at the National Research Council for Economics, Humanities and Social Sciences [NRC]), recruitment processes (at universities) and evaluations of funding programmes, institutions, research and education.

- **Recommendation 4.5. Create incentives for researchers to participate in international collaboration.** Today, there is an incentive to apply for national research grants under the project-based system, and international collaboration is seen as presenting additional transaction costs without the benefit of additional recognition. This situation leads to a low number of international co-publications compared to other OECD countries. Including international collaboration projects and co-publications as a recruitment, evaluation and career progression criterion would incentivise enhanced collaboration. Specific grants for international co-operation projects could be provided, along with assistance to overcome administrative hurdles that may arise on such projects.

- **Recommendation 4.6. Foster internationalisation of industrial R&D.** R&D activities of foreign-owned firms can generate considerable knowledge spillovers and economic benefits for host countries (see, for example, (Veugelers and Cassiman, 2005[1]); (Dunning and Lundan, 2008[2])). Similarly, overseas R&D activities of multinational firms can help them adapt products and services to new markets and enter global value chains (GVCs). It can also help multinationals tap into new talents and technologies, complementing a company's business strategy. Firms engage in international R&D networks if a number of conditions are fulfilled. Besides governmental and macroeconomic stability, these include international mobility of researchers, inward and outward foreign direct investment (FDI) flows and intellectual property (IP) protection. Korea is below the OECD average for these three indicators. With regard to IP protection, firms are, for instance, often reluctant to share intellectual property as IP protection is perceived to be low, leading them to favour secrecy over sharing intellectual property with foreign firms and personnel.

Recommendation 5: Enhance skills and attitudes in order to gain a leadership position in innovation

Overview

Korea's education system produces a high number of tertiary-educated individuals with above-average representation in science, technology, engineering and mathematics (STEM) disciplines. It provides an excellent basis for technical and theoretical skills and knowledge. Nevertheless, Korea needs to achieve a step change to gain a leadership position in innovation: it needs to boost creativity, entrepreneurial learning and risk acceptance. Korea also needs to better attract and leverage the influx of foreign talent.

Detailed recommendations

- **Recommendation 5.1. Actively encourage and celebrate risk taking.** Launch high-profile initiatives to promote ambitious and bold actions, targeting new generations of potential entrepreneurs. Risk taking needs to be actively encouraged and celebrated with initiatives to emphasise the importance of taking risks and accepting potential failure as a natural complement to success. Korea should further develop communication campaigns celebrating entrepreneurs and risk takers as well as prizes for entrepreneurs.
- **Recommendation 5.2. Expand the use of innovation challenge prizes.** Innovation challenge prizes can stimulate positive public perceptions toward innovation, mobilise talent and capital and strengthen problem-solving practices involving various stakeholders. Korea could benefit from innovation challenge prizes by showcasing creative problem-solving innovation best practices to promote risk taking, especially among youth.
- **Recommendation 5.3. Align human resource policies to encourage risk-taking behaviour.** Examine incentive structures in higher education and public research organisations to analyse the potential adverse impact of risk taking on individuals' careers. Incentivise risk taking and ensure that negative outcomes resulting from professionally correct behaviour do not bear punishment, i.e. if negative outcomes arise due to external factors, this is not imputed to the professional in charge.
- **Recommendation 5.4. Increase the emphasis on entrepreneurial education** in the curriculum for younger generations and adults looking for a career change. Exchanges and study trips to other developed countries can be beneficial. For example, the 2013 initiative of sending venture capitalists to Silicon Valley allowed them to become familiar with risk-taking practices and investing successfully in early-stage companies.
- **Recommendation 5.5. Facilitate entrepreneurial leaves of absence from universities and government research institutes.** This would enable an academic to start a business, e.g. by taking unpaid leave from their institution, and have a guaranteed return to employment in case of failure. Korea should also consider modernising career progression and pay policies currently based on seniority and ensure that staff using an entrepreneurial leave of absence are not penalised.

  In order to encourage the development of more young and highly-talented entrepreneurs, particular emphasis should be placed on mentoring. Stimulating the secondment of undergraduate and graduate students to innovation-oriented companies could be beneficial not only to shaping entrepreneurial mindsets and enriching experiences in industry but also for SMEs that face a talent shortage in terms of adopting advanced technologies.
- **Recommendation 5.6. Strengthen critical-thinking skills and creativity** in primary and secondary education by allowing more diversity in types of schools and curricula. Introduce more diverse subjects and increase the emphasis on critical-thinking skills and creativity in university entrance examinations.

- **Recommendation 5.7. Strengthen programmes for the formation of practically relevant AI skills in the higher education system.** Provide easily accessible digital technology training programmes for SME managers and employees to increase their awareness of the potential of digital technologies and enhance their digital skills.
- **Recommendation 5.8. Evaluate university-level entrepreneurial education programmes** based on their content quality instead of relying on quantitative metrics only. Provide financial incentives to incubators and accelerators for hiring experienced staff to facilitate the provision of high-quality coaching and mentoring services by experts such as former entrepreneurs and venture capitalists.

1.1.2. Pillar 2: Recommendations concerning business innovation

Recommendation 6: Strengthen the role of the service sector in the knowledge-based economy

Overview

While continuously supporting strengths in the manufacturing sector, Korea needs to prepare for an increased role of services, particularly high value-added services, such as licensing of intellectual property, ICT services, media, financial services and other business services that can also have strong export prospects.

Detailed recommendations

- **Recommendation 6.1. Develop a dedicated service innovation strategy and action plan.** Such a strategy should be built based on a prospective study evaluating the opportunity to develop high-value-added services, such as intellectual property licensing, ICT services, media, financial services and other business services for innovation, growth and competitiveness. It should be developed in a broad consultation, considering Korea's strengths and prioritising knowledge-intensive service sectors with considerable growth potential.

  Improved co-ordination is necessary between ministries and funding agencies to foster R&D in humanities and social sciences, along with science and technology R&D in STEM disciplines. To better support service R&D, it is important to increase its budget and programmes and establish a separate evaluation system tailored to its unique characteristics, including technology transfer, different from the evaluation system used for manufacturing R&D.

  An action plan should describe specific instruments, timelines, responsible institutions and monitoring mechanisms. Examples of measures could include financial incentives for service innovation (such as grants targeted at innovation in services), specific policies to enhance critical skills for service industries, as well as actions to raise awareness about service jobs as potentially attractive relative to manufacturing.
- **Recommendation 6.2. Address remaining regulatory restrictions on trade in services,** such as foreign equity limits, requirements for foreign service providers to establish a local presence and register, and limitations on their mobility and duration of stay. This could considerably increase the "servicification" of the economy and increase trade in services. This would strengthen not only the competitiveness of the services sector but also the manufacturing industries that rely on service inputs. The Korean government has successfully implemented the regulatory sandbox as an interim policy measure to ease regulations on critical service industries, particularly finance, and to adopt disruptive technologies, especially in the ICT sector. Korea should continue its efforts in this regard. Furthermore, if the regulatory sandbox can facilitate the creation of innovative business

models in heavily regulated sectors, the Korean government should take further steps to eliminate outdated regulatory restrictions in the service sector more broadly.

Recommendation 7: Strengthen the diffusion of innovative technologies to SMEs and support the global connectivity of start-ups

Overview

While Korea has an excellent digital infrastructure, the diffusion of digital technologies to SMEs has been slow. SMEs' absorptive capacity and the pace of their digital transformation can be enhanced through initiatives to strengthen their technology readiness and leverage existing skills more effectively. Furthermore, while start-up entrepreneurship is vibrant in Korea, it can be strengthened further through measures to enhance entrepreneurs' digital proficiency and improve the global connectivity of the start-up ecosystem.

Detailed recommendations

- Recommendation 7.1. **Boost diffusion of digital technologies** by reducing stringent product market regulations, particularly on e-commerce platforms, barriers in service and network sectors and barriers to trade and investment.
- Recommendation 7.2. **Enhance the quality and quantity of labour force skills in SMEs to accelerate the digital transformation.** Low ICT adoption by SMEs is contributing to the large gap in productivity with large conglomerates. To increase the uptake of ICT, the quality of labour force skills could be improved through specialised digital skills training and lifelong learning programmes. In addition, the untapped labour force of women and retired able workers could be incentivised to work in start-ups and SMEs through flexible work arrangements and fiscal incentives, thereby increasing Korea's potential labour supply.
- Recommendation 7.3. **Strengthen SMEs' access to digital and other emerging technologies** by building on recent measures taken during the coronavirus (COVID-19) pandemic to digitalise public services and by supporting the provision of advisory services for helping SMEs tailor digital tools and technology watch services.
- Recommendation 7.4. **Reduce the administrative burden in the provision of government support for start-ups.** This is particularly important in the case of business innovation support at the seed and scale-up stages, which are critical to the success of start-ups. Policies such as the National R&D Innovation Act, which consolidated the existing 264 R&D regulations for each department into a single rule, are indicative of progress already made in this area.
- Recommendation 7.5. **Strengthen the global connectivity of the start-up ecosystem** by conducting more international events that help Korean start-ups connect with relevant foreign experts and by supporting start-ups in developing globally competitive business models and entering foreign markets. To strengthen the global connectivity of Korean start-ups, advice programmes for developing overseas markets could also be valuable, particularly for high-tech start-ups that should cater to an international market.
- Recommendation 7.6. **Remove barriers for firms to invest in data and complementary intangible assets, including software and databases.** Evidence shows that SME productivity growth suffers from barriers to the use of intangible assets as collateral in asset-based financing, which can impede initial investment in these types of assets. Reviewing accounting practices and improving the measurement of key intangible assets is also important.
- Recommendation 7.7. **Implement government support programmes for the adoption of digital technologies by SMEs in a flexible manner aligned with companies' needs.** While the diffusion of digital technologies to SMEs can be enhanced through governmental support

programmes, such programmes are most effective when support for the introduction of digital tools is tailored to individual company needs. An example includes the Korea AI Manufacturing Platform, a "smart factory" initiative where the government makes parallel efforts to establish a database of manufacturing data while private sector providers establish "smart factory" services to manufacturing firms. A holistic approach could provide for broadening the scope of services included to encompass not only manufacturing process optimisation but also energy efficiency, carbon footprint, waste optimisation and other relevant issues. It could also help expand the concept to service sectors, which could benefit from similar improvements.

- Recommendation 7.8. **Promote and disseminate good practices for SME collaboration with large companies, other SMEs and GRIs.** Government support for collaboration should be comprehensive and enable SMEs to create diverse collaborative models, such as: 1) with large companies, to strengthen and expand the value chain; 2) with other SMEs, to share knowledge and experiences within the industrial complex; and 3) with GRIs, to improve R&D capacity.
- Recommendation 7.9. **Increase access to finance for start-ups and strengthen the exit model for a sustainable start-up ecosystem.** Korea has significantly improved financial support for start-ups recently. On top of the current various supporting programmes, equity crowdfunding, which is not among the largest in the current set of programmes, could become a significant vehicle for improving financial access. International good practices show equity financing also has merit in terms of entrepreneurship promotion and research commercialisation.

  Weak exit mechanisms, in terms of mergers and acquisitions (M&As) and initial public offerings (IPOs), have been recognised as a chronic problem in Korean start-up ecosystems. Recent policy changes that permit large companies to own corporate venture capital (CVC) for M&As of prominent start-ups are a step in the right direction, but further IPO and CVC deregulation could enhance start-up finance.

Recommendation 8: Streamline and assess the impact of public support on R&D and innovation

Overview

While Korea's business R&D and innovation are strong, they can be further enhanced by addressing various imbalances and strengthening the role of SMEs, foreign multinational enterprises (MNEs), and creative industries in business innovation.

Detailed recommendations

- Recommendation 8.1. **Reduce regulatory barriers to business entry and exit,** such as excessively stringent bankruptcy laws and barriers to entry in certain sectors, such as accounting, legal, telecoms, broadcasting, and air and rail transport.
- Recommendation 8.2. **Strengthen the global integration of Korean business innovation** by cutting red tape and making it easier for foreign MNEs to do business in Korea. Encourage collaboration on innovation between Korean and foreign firms to enhance MNE investment in research labs in Korea.
- Recommendation 8.3. **Maintain support policies for R&D and innovation by SMEs, including start-ups, while simplifying innovation support.** Decrease complexity by consolidating support into fewer and broader programmes and decrease the administrative burden for applications and reporting of outcomes. Market needs could be the most important criterion to streamline and monitor government support programmes since the accommodation of market signals is likely to enhance the relevance and quality of programmes. The Tech Incubator Program for Startups (TIPS), a widely recognised and successful start-up support scheme, validates the efficacy of a

market-based approach in Korea's business context. This type of market need-based programme evaluation could also be applied to new government support programmes in the form of demand assessment. Korea should also provide appropriate incentives for all innovation activities (including service innovation).

- Recommendation 8.4. **Upgrade the evaluation of publicly supported business R&D and innovation activities** by including qualitative outcomes and quantitative indicators. Encourage radical innovation alongside incremental innovation by providing support for explorative, long-term projects and not tying subsidies to short-term and quantitative outcomes only.
- Recommendation 8.5. **Provide public support for collaborative innovation activities,** such as through the widespread introduction of innovation vouchers that are easy to obtain and use. Encourage technology collaboration between large and small firms (e.g. through collaborative platforms and R&D tax credits) to facilitate technology diffusion to SMEs.
- Recommendation 8.6. **Strengthen support for green innovation,** including green hydrogen and carbon capture, usage, and storage through technology demonstration and deployment programmes, as well as public investment in clean technology infrastructure and networks (e.g. clean power grid extensions and battery storage facilities, electric vehicle (EV) charging stations).
- Recommendation 8.7. **Broaden government support policies for creative industries,** from the provision of financial incentives and export promotion to cultural and global exchanges among creative industries. Encourage Korean entertainment and gaming companies to engage in more responsible and sustainable employment and training practices.
- Recommendation 8.8. **Assess the impact of the current R&D tax credit arrangements** and consider adapting to achieve the best value for money, notably by incentivising academia-business collaboration and collaboration between large and small firms. R&D tax credit arrangements in a number of countries offer significant additional incentives for collaborative research and generate benefits beyond the tax credit received when R&D is undertaken in-house. Furthermore, based on re-examining the design of the R&D tax credit, Korea should focus on strengthening disruptive innovation in firms (often in the service sector). Evidence from OECD countries shows that R&D tax credits primarily favour incumbent firms rather than start-ups. Carry-over provisions or cash refunds, which could benefit start-ups, should be considered to strengthen the effectiveness of R&D tax credit incentives.

1.1.3. Pillar 3: Recommendations concerning the research system and linkages

Recommendation 9: Strengthen universities' ability to conduct relevant and excellent research to serve the needs of Korean society

Overview

The Korean higher education system faces a number of rather daunting challenges, some of which are endemic and some exogenous. The government needs to find more effective ways to encourage and incentivise universities to become stronger institutions (independent, strategic, resilient, relevant and impactful) to handle these challenges for the benefit of both universities and society. This requires rethinking the role of government to become more effective in "nudging" (incentivising) such change.

Detailed recommendations

- Recommendation 9.1. **Strengthen the autonomy of universities and their ability and incentives to become more resilient, relevant and impactful, both nationally and internationally.** This could include:

- Promoting excellence and strategic development through long-term funding (similar to Finland's Flagship Program) instead of the current system of rather small-scale project funding. Part of the funding could be based on long-term strategies and mid-term performance contracts, impact evaluations and programmes that encourage strategic profiling of universities (with regard to research, education and general mission – in particular, addressing societal challenges).
- Strengthening the autonomy of universities, coupled with providing long-term funding, carrying out internal governance reforms and improving strategic management capacity to allow universities (along with public research institutes [PRIs]) to play a key role in implementing national priorities and missions.
- Reviewing current incentive structures at universities and their impact on research excellence, industry-academic co-operation and internationalisation, and adjusting those incentives to better match desired objectives such as net-zero and the digital transition.
- Moving from rather onerous funding allocation and project supervision towards more effective "nudging" (incentivising) of universities to become more strategic, differentiate themselves more, support more breakthrough research, and change recruitment systems. Currently, funding is frequently allocated formally in competition, where universities and researchers dedicate considerable time to filling out applications. However, almost everyone ends up getting funding, and there is little meaningful follow-up, a shift in behaviour or dialogue.
- Allocating funding to teams and encouraging collaboration among faculty across departments and institutions, including multidisciplinary research, for example, to address global challenges and national missions.

- **Recommendation 9.2. Upgrade evaluation and assessment.** Initiate discussions among universities, research funders and policy makers on how to shift research evaluation away from an emphasis on quantitative metrics (number of papers and patents) towards more qualitative assessments. The San Francisco Declaration on Research Assessment (which has not been signed by any institution in Korea) could serve as an inspiration. Incentivise actors to develop and try different approaches (at the university level, research funders, etc.). Produce regular quantitative and qualitative assessments of Korean research quality and long-term impact, taking into consideration international positioning (similar to the Academy of Finland's or the National Science Foundation's reports). The research and innovation assessment framework proposed in Recommendation 3.3 is a way to do this. However, this upgrade should be applied and mainstreamed throughout the research system for project, programme and institutional evaluation.
- **Recommendation 9.3. Enable and encourage research programme funders to promote more high-risk (and potentially more transformative) research and innovation at GRIs and universities.** This can be done by:
  - Adopting a portfolio management approach to R&I funding (i.e. an approach where not all projects are expected to be successful), as is the case in national missions.
  - Enriching and diversifying the research funding landscape by incentivising companies or wealthy individuals to use earnings or wealth to fund academic research (e.g. tax incentives, such as in Denmark or Sweden).

Recommendation 10: Continue strengthening government research institutes to meet the needs of government and industry in the post-catch-up period

Overview

Like PRI systems elsewhere, despite the frequent reorganisations and reforms of recent decades, the Korean PRI system still bears the marks of Korea's fragmented governance culture and its history of focusing on catch-up. Therefore, there is a need to reinforce the government's efforts in recent years to adapt GRIs better to national industrial and societal needs and to explore the potential for providing more holistic support to policy and smaller firms.

The GRIs organised under the National Research Council of Science & Technology (NST), which focus on science and technology and have been decisive in modern Korea's industrial and economic development, went through a "role and responsibilities" process in 2019, redefining their scope and tasks as Korea moves from industrial catch-up to advanced country status. One implication of this change is that the activities of the GRIs need to be more closely aligned with the evolving needs of industry and society, and the government can no longer dictate the specific tasks GRIs should undertake. Like universities, the GRIs need to be components in a national "knowledge infrastructure" supportive of the needs of the major Korean multinationals, other large Korean firms, and broader society in response to societal challenges. A stronger flow of knowledge from GRIs and universities will support the development of new companies and industries. At the same time, smaller and less capable firms inside and outside the supply chains of the major companies need to improve their technological capabilities to remain competitive.

Detailed recommendations

- Recommendation 10.1. **Building on the Role and Responsibility exercise in which government research institutes revisited their missions, the financing model of the GRIs could be tailored to their missions.** International best practices could be referred to and further developed according to the Korean context, such as research and technology organisation (RTO) models for some GRIs and national research institutes for others. This involves reinforcing GRI autonomy by rebalancing the funding currently dominated by project-based funding with term time horizons of up to three to five years, which are insufficient for developing lines of basic research.
  - On the one hand, there should be an increase in long-term institutional funding under the control of the GRIs themselves. This will allow the GRIs to establish and maintain market-relevant capabilities on which to build their other functions. Specific projects desired by the government can be satisfied via separate contracts.
  - On the other hand, encourage GRIs to achieve a greater proportion of income via contracts with the private sector and (where appropriate) with public authorities that respond directly to client needs and do not require government agency approval. In some cases, such as when supporting companies with limited absorptive capacity, it may be appropriate to support this activity using grants to cover part of the cost.
  - While GRIs should be permitted, and potentially even urged, to compete for project-based funding, particularly for collaborative research ventures with companies, universities and other GRIs, it is important to dissuade competition with the private sector for such funding, as it can result in crowding out the private sector.
  - Allow variation in the financial models of GRIs, based on their specific missions. GRIs needing to conduct large amounts of more fundamental research should receive a larger proportion of institutional funding than those whose other activities are less dependent on research.
- Recommendation 10.2. **Evaluate the performance of the GRIs in relation to their missions.** This entails:
  - Making the GRIs responsible for internal monitoring at the project and programme level, subject to the routine activities of the national audit.
  - Focusing the evaluation of GRIs on their impact on society while requiring break-even financial performance. Generate evidence about other kinds of outputs, but crucially also outcomes and – to the extent possible – societal impacts.
- Recommendation 10.3. **Increase co-production of knowledge between GRIs and universities to strengthen GRIs' more fundamental research capabilities, signal universities**

about the need for use-oriented fundamental and applied research, and increase the quality and relevance of graduate and undergraduate education. This can involve creating joint posts between universities and GRIs, adjunct positions for senior GRI researchers in universities, and allowing GRIs to host PhD students ad hoc and outside the graduate schools in universities. These joint initiatives could be supported by dedicated university liaisons in the tasks of top research management in the GRIs. The objective of strengthening the relationships between GRIs and universities could also be reflected in the formal missions of universities' top senior managers (e.g. "Innovation Vice President").

Recommendation 11: Further develop linkages between universities, government research institutes and business

Overview

To overcome the barriers between academia and industry, co-creation instruments should be designed to facilitate matchmaking and offer financial incentives that bridge the two communities. Unfortunately, these communities do not naturally mix, representing a "social failure" due to their radically different values, time horizons, lifestyles and social circles.

Detailed recommendations

- **Recommendation 11.1. Create incentives and governance arrangements in universities and government research institutes,** including ensuring collaboration with industry, is an official mission of universities and GRIs, at the same level as research (and teaching for universities). Set objectives for GRIs and universities alike concerning private co-financing and collaborative projects in general. Korea should also adapt the monitoring metrics by decreasing the importance of patent count and including: 1) commercialisation and royalty revenue; 2) co-publications; and 3) co-patenting.
- **Recommendation 11.2. Expand "seed" innovation vouchers** with low face value and accessible to SMEs with minimal administrative procedures to initiate a large number of co-operations between academia and industry.
- **Recommendation 11.3. Expand and systemise public-private innovation partnerships,** such as matching grant programmes within the project-based system, whereby government funds match the funds provided by industry for a specific R&D project. Such programmes are widespread in other OECD countries and allow enterprises to reduce the costs and risks associated with R&D and innovation. On the other hand, they can be more efficient than direct grants since the readiness of the industrial partner to pay half the cost warrants their legitimacy and market potential. Comparable and successful models, including the US manufacturing extension programme, should be further studied and referenced.
- **Recommendation 11.4. Further invest in high-visibility infrastructure for science parks and excellence centres, with good networking institutions and public-private governance to foster the development of true collaborative research.** For example, public-private co-operative excellence centres on AI could be further developed to cover different AI applications, including Electronics and Telecommunications Research Institute (ETRI), Naver, Kakao and other public and private actors, to create a Korean AI powerhouse. Similarly, on the Smart Factory initiative, public-private partnerships such as the Korea AI Manufacturing Platform (KAMP) could be further developed with public and private entities, including start-ups, to develop the concept beyond process optimisation and include energy optimisation, environmental optimisation (including carbon footprint) and ultimately expand the concept to service industries.

- **Recommendation 11.5. Organise "triple helix" (academia, industry, government) and "quadruple helix" (include civil society) events** around social innovation (resolving societal challenges). Such events could include specific competitions with grants as prizes for the best proposals.
- **Recommendation 11.6. Further develop technology extension services** that directly support local firms, bringing about pragmatic improvements in their operations and practices with commercially proven technologies. Technology extension services fall between basic business development services, such as business planning and basic marketing, and high-end R&D (such as technology transfer offices and centres of scientific excellence). Such services should provide technology development, transfer and services, proactively addressing SME needs rather than waiting for them to ask (or trying to "push" patents developed at the provider's own initiative). Such services can be provided by technology centres or by extending the task of some universities (as has been done in the US university system).
- **Recommendation 11.7. Develop (temporary) mobility schemes between the public and private sector,** facilitating leave of absence of public research faculty to do a secondment in industry and for researchers from industry to spend time in GRIs and universities. Further develop industrial Master of Science (MSc) and PhD programmes of a dual nature, combining academic studies with practical experiences in research facilities.
- **Recommendation 11.8. Foster the presence and effective functioning of proof-of-concept programmes.** Proof-of-concept programmes could be crucial in bridging the gap between academia's early-stage research and businesses' later-stage development by upgrading technology that is not yet market-ready and facilitating potential business model development.

1.2. Introduction

Korea has achieved remarkable economic growth, stemming from its continued investment in science, technology and innovation. Building on past success, the government recognises the importance of research and innovation, and STI has long been understood as a pillar of the country's economic development. The country leads in private and public R&D investment, the former being particularly high compared to global and OECD standards. It also benefits from a large skills base with an exceptionally large share of the population with tertiary education. On the digital front, Korea represents an exemplary case in terms of building a sound infrastructure, investing in cutting-edge technologies and setting up institutional frameworks for their development.

However, Korea is at a critical juncture where it may need to reconsider the role of STI in its future growth model. The challenges Korea is facing can be captured in two aspects. On the one hand, strong investment records in STI have come at a price, leaving many gaps in the economy and society. The discrepancies are particularly acute in terms of productivity, where the benefits of fast economic development are concentrated in certain sectors of the economy. Investment in applied research fields and industrial competitiveness have helped create companies of global renown but, at the same time, have hindered Korea from exploiting the full potential of its rich experiences and assets. Against this backdrop, on the other hand, Korea is facing a number of societal challenges both internally and externally. The new challenges call for new solutions, and depending on the country's preparedness and openness to novel approaches, such trends can be perceived as either opportunities or threats. Korean society is rapidly ageing, the economy depends economically and socially on carbon-intensive manufacturing industries, and despite the country's leadership, the digital transition may accelerate the already present divide in both the economy and society.

1.3. Overview of the Korean innovation system, its evolution and challenges for the future

1.3.1. Korea is on the path to becoming a global leader in science, technology and innovation

Starting in the 1960s and over the following three decades, Korea successfully transformed from a low-income to a high-income economy. Korea's catch-up process evolved from an inward-looking and import substitution industrialisation strategy into an outward-looking export growth strategy. STI played a central role, with GRIs facilitating the transfer of key technologies to Korea and their very quick adoption by industry, particularly the large conglomerates. In addition, during the 1990s-2000s, Korea undertook domestic reforms to liberalise its economy, which led to a gradual rise in the country's participation in GVCs, with the GVC participation index increasing from around 40% in 1995 to 56% in 2010 (OECD, 2021[3]),[4] and lowered barriers to FDI (the FDI regulatory index declined from 0.532 in 1997 to 0.143 in 2010) (OECD, 2020[4]). GDP grew by an average of 7.9% per year during the 1960-2000 period, and between 2011 and 2021, compound annual growth stood at 2.38%, thus still narrowing the income gap with advanced economies.

Korea is a digital economy leader supported by a sound digital infrastructure, propelled by the government's strong commitment to investment in new technologies and a vibrant and innovative private sector. Since the 2000s, Korea has been far ahead of other OECD countries in terms of fixed broadband penetration and currently has the highest percentage of fibre in total fixed broadband connections (OECD, 2022[5]), which is key to mobile network systems and rising data traffic driven by the digital transformation (OECD, 2020[6]). It was also one of the first movers in 5G technologies, with 5G subscriptions reaching 19.4 million (26.8% of total mobile subscriptions) by October 2021. Already in 2019, Korea issued a national 5G strategy, "5G+", to integrate advanced devices and services across upstream and downstream industries into the 5G infrastructure (MSIT, 2019[7]). In parallel, the government formulated the 2019 Five-Year Development Programme for Quantum Computing Technology and the 2020 Strategy for Artificial Intelligence. Major Korean ICT firms are also aggressively pursuing cutting-edge technologies. In 2022, Samsung announced it would invest USD 356 billion in semiconductors, biopharmaceuticals and telecommunications over the next five years to lead in new next-generation telecommunications and robotics industries. Moreover, in 2019, Korea ranked fourth among OECD countries in transforming its government into a user-driven and fully digital platform that helps ensure a more comprehensive approach to the digital transformation of the public sector. It is also increasingly using data-driven regulation as a complement to traditional regulatory tools, which, by improving transparency and reducing information asymmetries, can steer the market in the right direction (OECD, 2020[8]).

Korea contained the spread of the COVID-19 virus effectively from the early outset of the pandemic. Damage to its economy from the crisis was relatively limited, owing to the government's swift and effective measures to protect households and businesses. Real GDP increased by 2.6% in 2022 with continued strong export growth, rising investment and continued policy support (OECD, 2021[9]; 2023[10]). STI policies were driving Korea's efforts to navigate the health crisis. Both targeted sectoral and horizontal measures supporting digital cross-border sales, the automation of administrative processes and the establishment of digital one-stop-shops significantly accelerated SMEs' incorporation of digital tools, thereby increasing their ability to address business complications arising from COVID-19 early (Bianchini and Kwon, 2021[11]). Additional measures included the implementation of the self-quarantine safety protection app from the outset of the pandemic to better monitor symptoms and quarantine compliance, as well as applications to overcome the shortage of masks by providing information on real-time mask stocks (OECD, 2022[12]) by Korean information service firms Naver and Kakao.

Korea has the second-highest R&D intensity among OECD countries, driven by high business enterprise expenditure on R&D (BERD). Korea's gross domestic expenditure on R&D (GERD) represented 4.6% of GDP in 2020,[5] second only to Israel among OECD countries. The annual growth rate of R&D has been steady at 7% for the period 2011-19, growing faster in business enterprises (8%) than in government (4%) and higher education institutions (4%). The vast majority is attributed to exceptionally high BERD, which was also the second-highest after Israel among OECD countries (3.7% of GDP in 2020). Large firms spend 62.5% of the total, while the rest is shared among SMEs (25.4%)[6] and venture firms (12.1%) (Statistics Korea, 2022[13]). The composition of BERD by firm size and industry has remained largely unchanged for a decade. Expenditure for publicly funded research is also among the highest in OECD countries, as Korea ranks fourth in terms of government budget allocations for R&D (GBARD) after the United States, Germany and Japan. In terms of sector performance, public research is concentrated in GRIs more than in universities, with the highest level of government expenditure on R&D (GOVERD) among OECD countries (0.46% of GDP). Higher education expenditure on R&D (HERD) is slightly below the OECD average (0.38% vs 0.41%) (Statistics Korea, 2022[13]).

Korea's large investments in R&D and innovation in terms of human and financial resources appear to have only partially paid off in terms of increased innovation outputs. R&D outputs in quantitative measures, such as the number of patent applications and publications, are globally leading and steadily increasing: between 2006 and 2020, scientific publications per million inhabitants increased from 895 to 1 741 (OECD average 1 214). However, the productivity of scientific production remains low. For instance, the percentage of publications in the global 10% top-cited journals is around 8%, placing Korea in the bottom third of OECD countries (OECD, 2022[14]). Furthermore, the number of firms with self-reported innovations is relatively low, with about 40% (United States: 63%; Germany: 61%; Switzerland: 72%) (OECD, 2022[15]).

A highly skilled human resource base offers strong potential for future growth if utilised effectively. Korea’s share of the younger adult (25-34 years old) population with tertiary education stands at 70% and is the highest among OECD countries and partner economies (OECD, 2022[16]). Among those, STEM graduates represent 31%, above the OECD average of 27% (OECD, 2021[17]). In the most recent OECD Programme for the International Assessment of Adult Competencies (*PIAAC*) survey (OECD, 2019[18]), Korea scores significantly above average in literacy and numeracy, though average in problem solving in technology-rich environments (OECD, 2019[18]). However, the International Institute for Management Development (IMD)’s university education ranking based on an employer survey shows low employer satisfaction with Korean graduates, placing Korea at rank 48 out of 63 in 2020 (IMD, 2021[19]).

1.3.2. Striking a balance: Achieving economic growth and development for all in Korea

Korea has a wide productivity gap between the service and manufacturing sectors and between firms of different sizes. This is, for instance, reflected by the low value added per employee in services, which is only 60% of that in the manufacturing sector, a gap wider than in most OECD countries (OECD, 2022[20]).[7] Labour productivity in the ICT industries is the highest relative to total productivity among OECD countries at 280%. However, the disparities between ratios of ICT manufacturing and ICT services productivity to total productivity are the widest in the OECD, with 4.9 and 2, respectively (Germany: 1.7 and 1.5; United States: 2.3 and 2.2), showing that in view of Korea’s strengths in ICT, productivity in ICT services has more potential to grow (OECD, 2022[20]). In addition, despite the relatively high diffusion of digital technologies in Korea (in particular world-leading fixed broadband and 5G subscriptions), Korean firms, notably SMEs, still lag in the adoption of crucial technologies, not least because workers in SMEs tend to be older and less skilled in digital technologies, in spite of both horizontal and sectoral policies supporting the rapid uptake of digital technologies prompted by the COVID-19 pandemic (Bianchini and Kwon, 2021[11]). In an effort to support service industries, the government announced the Service R&D Promotion Strategy in 2020 and pledged to invest KRW 7 trillion (Korean won) for five years starting in 2021.

Significant regional disparities exist in Korea, particularly between the capital region (Seoul, Gyeonggi and Incheon) and the rest of the country. For instance, 64.5% of R&D organisations (universities, PRIs and firms) are centred in the capital region, and 69.8% of national R&D investment occurs in the capital region, while the rest is spread across the 15 metropolitan cities and provinces, each with less than 3% of the total (KOSIS, 2022[21]). Efforts to promote regional innovation include four additional special R&D zones ("innopolises") to foster the development of new technologies and their commercialisation. In 2019, 12 "innotowns" were additionally created to sharpen the focus on technology transfer from universities and GRIs to regional firms. The government seeks to transform the landscape and unleash the potential of regions by including the Regional Balance New Deal as one of the pillars of the Korean New Deal 2.0.

Korea's population is markedly polarised by age group, posing threats to economic viability. While the Korean STI system benefits from a highly educated younger population, the rising old-age dependence ratio is expected to be the second-highest in 2050 (OECD, 2022[22]).[8] Korea also showed the highest poverty rate after taxes and transfers for those between 66 and 75 years of age among OECD countries, straining the overall economy as fewer young people will have to bear the costs for an ever larger share of the old-age population (OECD, 2021[23]). Furthermore, the concentration of high-skilled young employees in cities risks exacerbating the already increasing inequality across age groups, largely due to the dichotomy between conglomerates and SMEs, leaving less skilled and, in particular, the old-age population in rural areas behind. Korea has the largest difference in tertiary educational attainment between the group of 25-34 year-olds (70%) and the 55-64 year-olds (25%) in the OECD (OECD, 2021[17]). The threat of increasing gaps in access to talent between large companies and SMEs crucially risks reducing the latter's innovation capabilities.

Gender equality has improved, but there is still much room for improvement. The female labour force participation rate increased from 49% in 1990 to 59% in 2020.[9] However, it is still below the OECD average of 65% (Switzerland: 80%; Sweden: 80.3%; Germany: 75.8%; Japan: 72.5%). Most of this increase has occurred in the services sector, which is less productive. Furthermore, only 24% of STEM entrants are women (Germany: 40.6%; United Kingdom: 32%) (OECD, 2022[24]). As part of Korea's most recent Basic Plan, of which four have been published since 2004 with five-year cycles, the dimension of "gender innovation" was included. This set a standard for a gender-responsive approach to innovation, aiming to improve female participation rates in science and engineering.

1.3.3. Several of Korea's strengths risk widening industry gaps even further

Korea exhibits a high productivity gap between large firms and SMEs, particularly micro-firms. More than 83% of Korean workers are employed by SMEs, the second-highest share in the OECD. The contrast is even larger when considering micro-enterprises with fewer than ten employees, which employ many more than the OECD average and contribute much less to the aggregate value added (OECD, 2019[25]). Furthermore, the high business concentration in leading companies is demonstrated by the fact that the four largest chaebols (Samsung, Hyundai Motor, SK and LG) accounted for 48.5% of sales among the top 71 business groups in Korea in 2020 (Pulse, 2021[26]). SMEs dominate the service sector, but their higher value-added activities are concentrated in manufacturing rather than services, and overall labour productivity levels of SMEs are only around 26% (OECD, 2022[27]) of that of large firms. Reasons behind their lagging performance include operational deficiencies due to low adoption of new technologies; a digital skills gap among old-age workers; and a dual labour market whereby large firms attract talent through better working conditions. Recent training initiatives launched by the Korean government have emphasised the importance of lifelong learning, including continuous upskilling of employees to ensure their preparedness for new technologies.

A traditionally strong manufacturing sector has allowed Korea to become an industrial powerhouse. The contribution of manufacturing to national income amounted to 27.1% in 2020, the second-highest share among OECD countries,[10] and has underpinned Korea's export-driven growth model. Korea continues to benefit from its world-leading competitive position in manufacturing. A strong manufacturing base may increase resilience towards external shocks and allow for the expansion of related services industries, which are often dependent on the strength of the former (Pisano and Shih, 2012[28]). In particular, the accelerated development of new technologies will create new competitive advantages for manufacturing companies that are able to integrate these technologies and develop innovative new service-based business models. This process, sometimes called the "servicification" of manufacturing, can help companies create new revenue streams, improve customer satisfaction and differentiate themselves from their competitors.

Compared with other advanced economies, Korea exports relatively few services; of those, a large part belongs to lower value-added sectors. Korea's 35% share of domestic value-added services exports in 2018 was significantly lower than the OECD average of 52% (Germany: 47%; Singapore: 71%; Switzerland: 56%) (OECD, 2021[3]). In addition, about 65% of Swiss exports in services are high value-added, notably royalties and license fees, financial services, miscellaneous business services and IT services. Singapore shows a comparable composition, whereas Korean services exports comprise markedly lower value-added segments, such as travel, transport and construction services (almost 60%) (OEC, 2022[29]). In contrast to the OECD average of 40.7%, Korea's employment in knowledge-intensive services stood at 28% of total employment (Singapore: 54.3%; Switzerland: 52.9%) (World Bank, 2022[30]). Adopting such a cross-country perspective suggests that a stronger orientation towards higher value-added services may offer Korea vast opportunities for growth while simultaneously strengthening related manufacturing industries.

Korea's service sectors would benefit from increased business expenditure for R&D for services innovation. With BERD in services only amounting to 10% of total BERD in Korea, compared to the United Kingdom (59%), the United States (37%) and Germany (14%) (OECD, 2022[14]), Korea could benefit from untapped potential by extending its focus to service industries. The manufacturing sector accounts for 87.5% of BERD in Korea (comparable to the People's Republic of China [hereafter, "China"] at 88.4% and Germany at 85.4%), of which 91.2% is in high and medium-high R&D intensive industries (Germany: 92%; China: 60.6%). On the other hand, only 10.6% is dedicated to services and 4.8% to information and communication services (France: 13.7%; United Kingdom: 15.5%; United States: 25%; Israel: 43.7%) (OECD, 2022[14]). The rise of the digital economy is driving the trend of "servicification", in which manufacturers increasingly offer services alongside their products. This trend offers the potential for significant innovation in services.

1.3.4. Korea has benefitted strongly from global integration but has yet to fully exploit its potential

Korea's embeddedness in GVCs has enabled and facilitated rapid economic advancement through its export-led growth model. The foreign value added (FVA) share of gross exports represents the country's integration in GVCs. In Korea, the FVA increased until the mid-1980s, followed by a downward trend until the 1990s, rebounding again around 1996 when Korea joined the OECD. The 1980s and 1990s were when Korea's technology import strategy started to materialise as its firms successfully shifted from light to heavy and chemical industries (HCI).[11] Korea escaped the middle-income trap by increasing its share of local value added in its high-value-added exports and constructing its own industrial base through technological catch-up, which allowed it to move up GVCs (Lee, Szapiro and Mao, 2017[31]). Korea still maintains a relatively high level of FVA at 32% in 2018, which is 11th among OECD countries, next to Estonia (35.3%) and the Netherlands (33%), and higher than comparator countries of similar size – France (24.3%), Italy (23.1%) and the United Kingdom (17.8%). Countries' sectoral specialisation shapes the extent of their backward and forward participation; a high level of FVA is typical of countries that specialise in advanced manufacturing, as they rely on imported inputs for exports. An interesting observation is that Korea's backward participation has decreased since 2015, which may indicate that it has moved to innovative activities that require a higher level of R&D intensity and increasing IP receipts as a share of GDP (World Bank, 2020[32]).

Several factors have revealed Korea's vulnerability to disruptions in global supply chains in high-technology sectors, pushing Korea to consider technology sovereignty as a policy priority. Currently, Korea faces a combination of global trends. This includes changing prices of intermediate inputs; the reshoring of certain production facilities by some countries; a reshaping of the regional context where China has increased its presence as a supply hub for global trade; and rising trade tensions with Japan. Geopolitical tensions between the United States and China could potentially impact Korea's position in high-technology sectors, considering its close ties with both countries. As a traditional ally of the United States, Korea is considered a country with which the United States can co-operate, e.g. in the semiconductor sector and others, such as large-capacity batteries and pharmaceuticals, while pursuing its efforts to increase the resilience of the global supply chain (The White House, 2021[33]). At the same time, China remains an important economic partner that accounted for 43.2% of semiconductor exports and 31.2% of imports in 2020, with the latter being mostly intra-firm trade with local fabrication plants of large companies, such as Samsung Electronics and SK Hynix (KIET, 2021[34]). In order to manage the immediate risks and seek long-term opportunities, relevant ministries jointly designated 12 "critical and emerging technologies"[12] that have strategic value for Korea. These technology areas will benefit from comprehensive government support, including increased R&D investment, tax benefits and technology protection measures.

Korea can alleviate the challenges by deepening the level of its regional integration. Notwithstanding that technology sovereignty has become more critical for Korea over the years, it should be balanced with efforts to diversify its trade partners and commodities, considering the relatively smaller size of the economy. While being deeply embedded in GVCs, Korea can offset the risks related to reliance on imports of intermediate goods by consolidating its regional integration, e.g. strengthening economic ties with the Association of Southeast Asian Nations (ASEAN) region. Since the Korea-ASEAN Free Trade Agreement came into force in 2007, trade in both directions expanded quickly, and in 2019, ASEAN was the second-largest partner for Korea in terms of trade volume (15.6% of total imports and exports). On the firm level, the growth potential of the region was well perceived by Korean firms, as evidenced by the partial shift to offshoring of large companies (such as Samsung and LG) to Viet Nam. The number of companies settling in Viet Nam or having created branches is bigger (3 234) than in China (2 233) (KITA, 2021[35]). However, Korea is facing growing competition, particularly with China and Japan, due to the similarity in merchandise trade structures of exports (IIT, 2019[36]). In order to compensate for this and to ensure the stability of trade relations with the region, engaging in deeper regional trade agreements could be considered an option. Regional trade blocs provide common disciplines that help address credibility issues and internalise cross-border policy spillovers (Ruta, 2017[37]). The effect tends to be stronger in sectors that are more deeply integrated in GVCs, which is the case for many high-tech sectors in Korea.

FDI, in particular towards knowledge-intensive sectors, is not yet leveraged to its full extent. Following its accession to the OECD in 1996, Korea has liberalised FDI, as witnessed by the fall in the OECD FDI Regulatory Restrictiveness Index from 0.532 in 1997 to 0.135 in 2020. This compares to the OECD average decrease from 0.127 to 0.063 in the same period (OECD, 2020[4]). Despite such significant improvement, Korea was still the sixth-most restrictive OECD country in 2020, remaining above the OECD average. Overall FDI inflows have stagnated at around 0.6-0.8% of GDP in recent years, about one-third of the OECD average (OECD, 2022[14]). While hardly any trade and investment restrictions apply to the manufacturing sector, some service industries, such as communications, pose conditions, including foreign equity limits of 50% (OECD, 2022[38]). Besides factors such as equity restrictions or limitations with regard to the mobility of key foreign personnel, evidence suggests that informal institutions also impact FDI decisions. Notably, strong social capital, meaning trust-based networks of individuals and local firms in which foreign entities can be integrated, positively drives inward investments (Mondolo, 2019[39]). In this regard, Korea has the potential to benefit from deepening business networks and global integration.

Korea is not fully leveraging its traditionally open policy towards talent immigration. The government has set up a comprehensive migration framework for foreign tertiary graduates. As a result, foreign students registered in Korean tertiary programmes increased by 91% during 2010-19, with the majority originating from East Asian countries. Even so, only 2% of university students are foreign nationals (KESS, 2022[40]). Similarly, immigration via professional routes, such as work-visit programmes for ethnic Korean foreign nationals, has seen an influx of Chinese migrants, who make up about half of the 3.7% of foreign residents among the economically active population. In 2003, Korea launched one of the largest temporary employment permit systems in the OECD, both in absolute numbers and relative to the labour force. It targeted SME personnel needs in particular, as SMEs are affected by shortages of employees with practical skills. In view of a drastically ageing population, these shortages for SMEs are likely to intensify. Korea has restructured its migratory framework to attract highly skilled workers by adopting various policy measures, including a points-based system allowing skilled migrants to settle based on the fulfilment of professional criteria and an accelerated path to permanent residency. Nonetheless, few international students and workers remain in the country long-term due to stringent working conditions and hierarchies; gender disparities; a highly competitive job market for tertiary graduates; difficulties in enrolling their children in the education system; and closed social networks (Shin and Choi, 2015[41]; InterNations, 2021[42]).[13] In addition, some regulatory complexities remain, such as around 170 sub-categories for study, employment and family permits (OECD, 2019[43]). Integrating skilled immigrants into the local labour force could spark new ideas, facilitate knowledge diffusion and foster the creation of new businesses, as they tend to have a higher propensity for risk taking.

1.3.5. Societal and structural challenges and Korea's preparedness for transitions enabled by science, technology and innovation

Korea has demonstrated a clear commitment to tackling societal challenges, which benefits from broad-based public support, e.g. combating climate change. According to the Green Future Index,[14] Korea is ranked 10th among the top 20 countries making the greatest progress toward building a low-carbon future, next to Germany and Sweden (MIT Technology Review, 2022[44]). Among the five pillars, Korea leads in three dimensions: "energy transition" (eighth); "green society" (first); and "clean innovation" (eighth).[15] The recent OECD survey on climate literacy shows that Korea is on par with the United States and European countries (Dechezleprêtre et al., 2022[45]; OECD, 2022[46]). The overwhelming majority of 94% out of 1 500 respondents answered that climate change is an important problem, and as in many OECD countries, climate policies received considerable popular support.

In terms of the green transition, Korea needs to overcome its reliance on carbon-intensive manufacturing sectors. The CO_2 intensity of GDP[16] in Korea dropped from 0.52 kg in 2000 to 0.28 kg in 2018 but remains above the OECD average (0.20 kg) and higher than its comparator countries (France: 0.10 kg; Germany: 0.15 kg; Japan: 0.21 kg; United States: 0.24 kg) except for China (0.47 kg). Korea also displays one of the highest energy intensities and ranks 92nd out of 143 countries as measured by the International Energy Agency (IEA) in terms of energy consumption per GDP (IEA, 2021[47]). The high performance of carbon-intensive manufacturing sectors, such as petrochemical, iron and steel, largely explains this. Korea's coal-fired power plants were the largest, both in absolute volume and by share in energy generation (which accounted for 86.9% of greenhouse gas [GHG] emissions in 2018) (Ministry of Environment Greenhouse Gas Inventory and Research Center, 2020[48]; IEA, 2021[47]). Fossil fuels accounted for 73% of power generation in 2018, of which coal was 44%.

Various policies have been put in place to support the green transition, but overarching concerns about economic growth and exports, employment, and geopolitics still take precedence over climate change. Since the 2010 Framework Act on Low Carbon, Green Growth created the legal framework for setting mid- to long-term emission reduction targets, the country has adopted the Korea Emissions Trading Scheme (K-ETS) and the GHG and energy target management system. More recently, in 2020, the Korean government committed to becoming carbon neutral by 2050 and reducing emissions by 40% in 2030 compared to 2018. Currently, 96.5% of emissions are covered by effective carbon rate, which puts Korea first among the Group of 20 (G20) countries, followed by Canada (88.2%) and Germany (88.1%) (OECD, 2021[49]). The government also defined a list of critical technologies that needed to be developed to realise carbon neutrality as R&D investment areas. However, as mentioned above, policy makers' focus on investing in technology,[17] where Korea is already performing better than any other economy, needs to be balanced with acknowledging and handling industry resistance to transformative change (e.g. in phasing out fossil fuels). A need remains to formulate more specific action plans towards reducing GHG emissions over the next decades (Lee and Woo, 2020). As a start, Korea recently introduced policy measures, such as the Support Measures for Fair Job Transition, in response to industrial structure change in order to increase social responsiveness to the green transition.

Within the private sector, there is an increasing emphasis on corporate social responsibility and environmental sustainability, although it remains unclear to what extent Korean companies have altered their behaviour towards more sustainable practices. Many companies work towards receiving high corporate environmental, social and governance scores, which are widely calculated and published. As per K-ETS, since the start of its first phase in 2015, the three highest-emission industries in the manufacturing sector[18] saw a significant increase in carbon productivity after participating in the scheme (Jung et al., 2021[50]). Also, as of 2021, 13 Korean companies, including large conglomerates such as SK Hynix and LG Energy Solution, have joined the Renewable Energy 100 (RE100) campaign, a voluntary initiative that brings together over 300 companies worldwide committed to 100% renewable energy to power their operations.[19] In particular, Korean conglomerates have assumed leading roles in specific green technologies, such as the manufacturing of batteries for electric cars. However, the rapid introduction of carbon reduction targets is widely perceived as a threat to companies' competitiveness and jobs. Thus far, the Korean track record on mitigating global warming is not positive, as carbon emissions per unit of GDP are high and have increased until 2018. Unless emissions are reduced soon, Korean exports may face carbon import taxes in other countries.

Korea faces declining growth prospects due to rapid ageing, adversely affecting its labour supply. With skilled labour among the most critical factors determining a country's success in innovation, having a sufficiently large and tech-savvy labour force is vital to reducing skills mismatch. Korea's projected economic trajectory shows particularly high vulnerability to this trend, most notably when considering the very long term. As such, the annual GDP growth rate is projected to reach the lowest level among OECD countries in 2030-60, at 0.8%. By 2050, more than one-third of the population will be over 65, while over half of the labour force will be above 50. More specifically, the 10.8% growth rate in the number of seniors between 2000 and 2018 was already the second-highest among OECD countries, far exceeding the 4.1% OECD average (OECD, 2021[51]). This is partly due to the widespread seniority-based approach in human resource management practices, where senior employees are pushed to leave their jobs around the age of 50 (mandatory early retirement or "honorary retirement") to settle in low-productivity service sectors with their severance payments (OECD, 2018[52]). These trends underscore the importance of previously mentioned imperatives, such as lifelong learning, as the old-age workforce will become increasingly important for Korea's economy by size. In parallel, this increases the need for skilled employees who are knowledgeable in contemporary technologies. In the meantime, the shrinkage of the talent pool is at this stage unlikely to be significantly compensated by an influx of skilled migrants, considering its slow evolution.

Korea's restrictive product market regulations may also hinder progress in digitalisation in terms of pursuing cutting-edge innovation and diffusing existing technologies. Korean product market regulations are among the most restrictive among OECD countries, imposing barriers to trade, competition and business operations. In 2018, it remained among the most restrictive OECD countries in terms of state involvement in business operations, including in price controls, command and control regulation, as well as trade and investment regulations, such as tariff barriers and restrictions in the service sector (OECD, 2022[53]). These restrictions limit market competition and thus may impede investments in innovative digital technologies needed to remain competitive. They also hurt productivity growth with specifically adverse effects for SMEs.

The digital transformation, despite its benefits, has the potential to accelerate digital and other divides. For all OECD countries and beyond, the rising demand for ICT skills poses the threat of widening the gaps in income and productivity between age groups, large companies and SMEs, to a larger extent in Korea, as well as the geographical divide between more and less innovative regions, unless addressed by appropriate policies. Despite the continuous policy attention given to its traditionally strong ICT sector and emerging technologies, Korea is at particular risk for all of these factors since it is expected to have the highest population dependency ratio in the world by 2060, which may be exacerbated by aggravating generational educational gaps (OECD, 2018[52]). Therefore, the digital transformation may also further widen the productivity gap between SMEs that face a shortage of skills, and thus, absorptive capacities for technology diffusion, and large firms that benefit from top talent. This may, in turn, further increase the concentration of innovative activities in urban areas. Furthermore, as data becomes increasingly important for innovation, those firms with superior access will benefit disproportionately, potentially increasing market concentration within and across sectors.

Conversely, digital technologies could help reduce such divides if effectively disseminated throughout society. They often require less fixed ICT investments (e.g. cloud computing alleviates the need for large storage capabilities) and increase productivity. The digital transformation also offers better access to public services across demographics and geographies and facilitates teleworking, which may lead to workers settling in rural areas for a better lifestyle; such trends should be encouraged. Moreover, the digital transformation has the potential to spur the development of new industries, such as data centres and smart factories, which are often located on large manufacturing sites outside of major cities and can contribute to reducing regional disparities.

1.4. Business sector R&D and innovation in Korea

Korea's developmental catch-up strategy has helped the country build a dynamic business sector that acts as an engine for the growth of the knowledge-intensive economy. Despite this impressive achievement, there remain widespread discrepancies in innovation and productivity among firms, notably between a small number of extremely successful conglomerates and under-performing SMEs and within industries between world-leading manufacturing and a lagging service sector. Furthermore, as outlined earlier, Korea faces several headwinds that require immediate action sustained over the next decade or two. These include global technology competition; demographic and labour market challenges; income and social inequality; and climate change, all of which will affect the ability of Korea's business sector to remain a source of growth and competitiveness in the future.

1.4.1. General diagnosis of Korea's business sector R&D and innovation performance

Korea's business R&D investment is very strong. At first glance, Korea's business R&D and innovation performance is strong in quantitative terms. Korean firms' R&D expenditures have more than doubled in the last decade, from USD 39 billion in 2010 to USD 82.3 billion in 2019. Business R&D intensity amounted to 3.73% of GDP in 2019, the second-highest among OECD countries. However, a closer examination reveals some fragilities in Korea's business R&D structure. Not only is business R&D heavily concentrated within industrial conglomerates ("chaebols"), ten of which accounted for 47% of business R&D in 2019, but the growth in business R&D has been led by only four of these chaebols, suggesting that business R&D spending in non-leading chaebols is weaker (Chung and Ratnovski, 2016[54]; Shin, 2017[55]). The concentration of R&D expenditures can be both a strength and a weakness. It is a strength because large chaebols rely less on external finance for R&D investment. However, it may also be a weakness, potentially exposing Korea to the "Finnish scenario", where the failure of a major technology group (Nokia) to anticipate market and technology changes led to a drop in R&D spending and associated knowledge spillovers throughout the economy.

Korea is among the world leaders in patenting, especially ICT patents. Korea has established itself alongside innovation leaders such as Germany, Japan and the United States as a major player in technological innovation. The number of Korean patents filed under the Patent Cooperation Treaty (PCT) increased from 8 731 in 2009 to 15 523 in 2017, while its share of PCT patents in the ICT and biotechnology industries grew from 9.6% and 4.2% of the OECD total in 2009 to 11.9% and 7.5% in 2017, respectively (OECD, 2021[56]). At the same time, patenting in the new growth sectors, including green technologies such as hydrogen, battery storage or carbon capture storage technologies, has been increasing, and Korea is catching up with some key competitors. For example, concerning hydrogen technology development, Korea (0.90) is approaching the level of Germany (1.19), Japan (1.17), Austria (1.05) and Denmark (0.98) in terms of global patent applications per million population in 2018.[20] However, technological progress in green tech is more complex than technological innovation in the ICT sector for several reasons. For one, private investment in green technologies is subject to many market and policy failures, such as the inability to price in negative externalities from CO_2 emissions, for example, through carbon pricing. While Korea has the most advanced carbon emissions trading scheme in Asia, carbon prices have decreased to an average of EUR 10.34 per tonne of CO_2, down by EUR 3.96 since 2018 (in real 2021 euro) (OECD, 2021[49]). Another reason is that clean energy innovation, especially at its frontier, relies on strong input from basic science and builds on a strong relationship between business and public research, an area where Korea needs further improvement.

From a qualitative perspective, Korean firms' innovation performance is significantly less strong. The OECD 2019 release of *Innovation Indicators*, which provides a country-level aggregate picture of innovation performance, placed Korea at 25th out of 36 OECD countries and partner economies (OECD, 2020[57]). More specifically, between 2017 and 2019, 23.8% of Korean manufacturing companies introduced a new product, and 28.3% developed a new business process, whereas, for the EU27, the respective shares were 25% and 30.3%. Firms mostly rely on formal R&D, internal sources of information and in-house activities when innovating. Most innovation is incremental, with 85.9% of firms focusing on improving goods and services compared to 39.8% that seek to introduce new products and services. Furthermore, Korean manufacturing firms' self-assessed degree of innovativeness is low, with a reported score of 3.0 on a scale of 1 to 7 (STEPI, 2020[58]).

Meanwhile, the internationalisation of business R&D is comparatively low. R&D spending is dominated by domestic companies, with only 3.9% of all R&D in manufacturing industries due to foreign companies in 2018. R&D by foreign companies is increasing, albeit from a very low base of 60 foreign entities engaged in R&D activities in 1999 to 375 in 2014 (Hemmert, 2020[59]). In addition, business R&D mostly consists of firms' in-house activities. The relative share of external R&D is only 6% of all R&D expenditures in 2019, compared to 23.7% in Germany in 2017 and 17.2% in Japan in 2020 in the manufacturing sector (KISTEP, 2021[60]).

Korean firms recognise the need to innovate, but most face significant barriers. The high cost of innovation and a lack of internal finance and access to information are the most frequent innovation barriers for Korean firms (STEPI, 2021[61]). While large firms tend to innovate frequently and successfully by leveraging their strong in-house R&D resources and capabilities, there appears to be a lack of technology diffusion to SMEs due to the inability to attract the best and brightest, who are hired into the conglomerates.

1.4.2. Imbalance in R&D performance between large firms and SMEs

While the high share of R&D performed by large firms is not unique to Korea, the concentration is much higher than in other developed countries. Some 47% of corporate R&D is undertaken by Korea's top-ten largest companies. Further, the R&D expenditure of the top 30 sales companies has risen, whereas the R&D expenditure of companies with sales rank from 31st to 70th has decreased year on year (KISTEP, 2021). Furthermore, OECD analysis of start-ups indicates that young businesses in Korea significantly contribute to net job creation but have a low survival rate and low average employment growth after entry (OECD, 2020[62]). In addition, access to finance, bankruptcy regulations and contract enforcement have been found to play a very important role in explaining cross-country differences in young firms' employment growth, e.g. (Calvino, Criscuolo and Menon, 2016[63]). These characteristics hint at the possible existence of barriers to scaling up.

SMEs are the primary focus of governmental support for business R&D, but the fragmentation of support programmes could be reduced. Korea ranks among the OECD countries with the highest level of total government support to business R&D as a percentage of GDP, at 0.29% in 2019. In 2019, SMEs accounted for 77% of R&D tax relief recipients, while the share of R&D tax support accounted for by SMEs amounted to around 54% (OECD, 2021[64]). At the same time, the generosity of tax incentives for large firms has been steadily reduced over time and is relatively low among OECD countries. Furthermore, while tax credits for large firms are capped at 2% of R&D spending, there is no ceiling for the R&D tax credits for SMEs, so the implied R&D tax subsidy rate for profit-making SMEs was 26% in 2021. Although there is no apparent negative effect on business R&D at the aggregate level, it is still necessary to conduct a more comprehensive evaluation of how this has affected the R&D investment of large firms. Meanwhile, direct support for SMEs is rather fragmented across many field-specific programmes run by government agencies. The online portal for SME support policies created by the government lists over 400 separate programmes related to technology support. While a minor part of the subsidies needs to be paid back for non-successful projects, performance evaluation standards are lenient. The highly specific scope of many support programmes could lead to inefficient use of public resources, causing possible overlaps between different programmes and, at the same time, hindering individual programme recipients from utilising the best resources.

1.4.3. A wide productivity gap between ICT and non-ICT industries

Korea's ICT industry has achieved remarkable growth and maintained robust potential for further innovation. Its competitiveness is outstanding on the global stage, and the industry has been a main driver for economic growth in Korea. Korea ranked top in ICT value added (10.4%), ICT employment rate (4.6%) and the ICT patent ratio (62.8%) in OECD countries (OECD, 2017[65]). Meanwhile, from 2010 to 2018, the share of domestic value added in knowledge-intensive industries has substantially increased; however, it was not created equally across business sectors. In particular, value added in ICT has increased by 75%, outpacing other manufacturing industries (29.2%).

The productivity gap between ICT and other industries is significant. The Korean economy's success formula, export-led growth in key manufacturing industries and targeted support to a small set of information technology (IT) sectors drove growing productivity gaps in Korea. While the productivity of Korean ICT manufacturing stands at 294% of economy-wide productivity, compared to 163% for the OECD average, the productivity of other sectors remains at half that of ICT manufacturing (OECD, 2020[62]).

1.4.4. Large discrepancies between manufacturing and service industries

Service firms perform little R&D compared to manufacturing. The share of non-manufacturing R&D among business R&D in Korea was only 10.6% in 2019 (KISTEP, 2021[60]), compared with an average of 29.2% across the United States, Japan, Germany, the United Kingdom and France in 2016 (OECD, 2021[56]). Furthermore, the R&D intensity (the ratio between R&D expenditures and sales) is much higher among Korean manufacturing firms than service firms. It was 4.49% in the manufacturing sector and 2.21% in the service sector in 2019 (KISTEP, 2021[60]) (KISTEP and Ministry of Science and ICT, 2019[66]).

There is a wide productivity gap between the manufacturing and service industries. Productivity in the service sector is 43% of that in manufacturing (OECD, 2020[62]). The productivity gap mirrors wage disparities, leading to a lack of talent in service industries. Furthermore, another significant disparity between manufacturing and services can be found in GVC integration. While Korea ranked 7th among manufacturing hubs in GVCs, it ranked only 21st among services (OECD, 2021[3]).

In addition, there is scope to increase value added in both services and manufacturing. With the development of ICT technologies, services are increasingly embedded in manufacturing products, and Korea has the potential to increase the "servicification" of the manufacturing sector (OECD, 2021[67]). Korea is strong across manufacturing sectors, from more basic production industries like steel to advanced electronics, and high value-added services (including exports) typically originate from a strong manufacturing base. For example, there are many services attached to a Samsung cell phone or a Hyundai vehicle, but few domestic services are embedded in manufacturing. In fact, the contribution of domestic services to manufacturing exports is one of the lowest among OECD countries at 15%, while the OECD average is 28% (OECD, 2021[3]).

1.4.5. Korea is building a vibrant start-up ecosystem

Korea has a vibrant start-up ecosystem supported by active government support policies. Enterprise birth rates, measured as the share of new enterprises over existing ones, are high in Korea, at 15.1% compared to 11.4% in France and 6.9% in Germany (OECD, 2022[27]). Furthermore, the number of technology start-ups, particularly in ICT and biotechnology, is increasing. Support policies for start-ups, amounting to nearly USD 1.2 billion in 2020, include direct measures, such as investment and R&D support, and indirect measures, such as support of entrepreneurship education, mentoring and consulting, workspace supply, and networking events. In particular, the government has played a dominant role in start-up finance throughout the last decade. However, although governmental seed funding is widely available, some start-ups do not use it due to a perceived high burden of paperwork. Recently, government and private funding of start-ups have been bundled through matching investment programmes (TIPS). In this programme, the selection of start-ups to be supported is outsourced to private accelerators.

Despite the rise in start-up finance, which amounted to approximately USD 31 billion in 2021, it remains insufficient to support the ecosystem. Failing to find domestic funding, some Korean start-ups turn to international sources when scaling up to reach the "unicorn" range. Furthermore, exit models for start-ups have been weak. Due to regulatory hurdles and limited interest by major technology companies in acquiring start-ups, there were few IPOs (114) and M&As (43) in 2019 (STEPI, 2021[61]). Only 23% of venture capital (VC) investment in Korea is recouped through IPOs and a mere 2% through M&As. In contrast, M&As account for 37% of total VC returns in both the United States and Europe. When combined with IPOs, they represent 94% and 54% of VC returns in the United States and the European Union, respectively (Asan Nanum Foundation, 2021[68]). While the situation is improving on both counts, engaging in serial start-up entrepreneurship remains challenging.

Mobilising entrepreneurs, encouraging a positive attitude towards risk taking and increasing diversity are essential. In 2019, Korea ranked 88 out of 141 countries for "Attitudes towards entrepreneurial risk" in the World Economic Forum's Global Competitiveness Report (World Economic Forum, 2020[69]). Furthermore, confidence in one's own skills and abilities to start a business is low (33rd), while starting a new business is perceived as difficult. Korean entrepreneurship remains below its potential due to a perception of insufficient opportunities. As reported by the Global Entrepreneurship Monitor 2021/22, Korea is 17th out of 19 countries in the high-income group in terms of perceived opportunities to start a business (Global Entrepreneurship Monitor, 2022[70]). Partially due to a lack of international exposure, most start-ups focus on developing business models, products and services for the domestic market. The ratio of newly founded firms expanding beyond Korea stood at only 2.2% in 2019 (STEPI, 2021[61]), and even fewer succeeded internationally. It is worth noting that, based on the OECD Product Market Regulation indicator, which measures the administrative burden on start-ups, Korea improved from 1.87 in 2013 to 1.09 in 2018. This is better than the OECD average but still far behind the top-five best-performing countries (0.49) (OECD, 2022[53]). According to the same source, Korea faces some of the highest barriers to domestic and foreign entry among OECD countries, particularly in service and network sectors, as well as trade and investment. These barriers may contribute to the perceived lack of opportunity for entrepreneurs. Improvements in promoting entrepreneurship could, therefore, be made. In addition, in order to diversify venues for growth, the biotechnology industry is a promising field to tap into.

Korea still depends on the ICT industry more than any other OECD country, but new technology-based industries, such as biotechnology, are emerging. ICT still has a dominant presence in the Korean economy, and some figures suggest that over the course of overcoming the havoc wreaked by COVID-19, dependence on ICT is increasing further. According to the Hyundai Economy Research Institute (HERI), the ratio of ICT value added to GDP is expected to increase from 10.8% in 2020 to 11.3% in 2021 (HERI, 2022[71]). Meanwhile, thanks to continuous government support since the early 1980s, when the Biotechnology Promotion Act was enacted and provided the legal framework governing support policies, the expansion of the Korean biotech industry has been impressive; many Korean firms are now leading globally in this area.

Public R&D investment in biotechnology has paved the way for the creation of a solid ecosystem. Government R&D investment in biotechnology increased significantly from USD 1.2 billion in 2007 to USD 3.4 billion in 2016, and from 15.7% of total government R&D spending in 2016 to 19.2% in 2020 (MSIT, 2017[72]; 2021[73]). Biotech firms have high R&D intensity, and biotech product development takes much longer with much less prospect of success than other manufacturing products. Strong and continuous government investment could encourage entrepreneurs to create and expand biotechnology-related businesses (Giesecke, 2000[74]). The number of biotech start-ups created in Korea rose from 140 in 2010 to 440 in 2016. The Korean biotech industry has become competitive globally, and Korea is now ranked second regarding the production capacity of biomedicine (MOTIE, 2021[75]). Total exports from Korean biotech firms also more than doubled, from USD 1.8 billion in 2016 to USD 4.4 billion in 2018. Furthermore, the workforce in the biotech industry has continued to grow; in 2020, it marked a 10% increase from 2019 (KBIO, 2020[76]).

1.4.6. Knowledge-based service industries offer the potential for value-added growth

Despite various policy measures by the Korean government to promote service industries, the results have fallen short, notwithstanding successes in some sectors. Previous work by the OECD has identified regulatory burdens, lack of competition, restrictions on foreign entry and other barriers to inward investment and competition from abroad as principal reasons for the weakness of the Korean service sector (OECD, 2014[77]). The Korean government has introduced numerous measures to boost service sector competitiveness over the past two decades. For example, to level the playing field between manufacturing and services, in 2016, the tax incentive for the service industry was shifted from a positive-list to a negative-list approach so that all service activities not listed in the law are, by default, eligible for tax credits. In 2019, Korea also introduced a regulatory sandbox in ICT convergence and financial innovation. Through the regulatory sandbox, firms can test their services and business models without being subject to all existing legal requirements. Meanwhile, the government has prioritised its policy to promote a few high-value-added service industries, including healthcare, education and software.

The software industry is growing with government support. Korea has actively promoted the software industry with a comprehensive policy mix based on the Software Promotion Law enacted in 1987. This law requires the MSIT to formulate a mid-term (three-year) plan to promote the software industry. The law also includes provisions for software-related R&D support, the development of human resources, policy loans and tax incentives, as well as standards and certifications. It also provides a legal basis for software pricing and contract terms with respect to public procurement. Recent policy measures to promote the software industry as a high-value-added service industry has concentrated on lifting regulation of public procurement and developing human resources. Until recently, large firms were not allowed to participate in public procurement of software to protect local small software firms. Starting in 2015, public procurement has gradually opened to specific large firms, such as in those emerging technologies. In order to provide software talent, the government has expanded the number of "software-centred colleges" to 44 as of 2022. Meanwhile, Korean software firms are actively expanding to overseas markets; exports doubled from USD 5.1 billion in 2012 to USD 10.6 billion in 2017 (IITP, 2019[78]).

1.4.7. Digital transformation presents a major opportunity but requires continuous policy attention

Korea has strong foundations for the digital transformation, yet there is room for improvement. It has the highest share of fibre connections in total broadband subscriptions (80.4%), as well as a high share of value added and employment in the ICT sector (OECD, 2020[62]). Moreover, Korea has a generally strong proliferation of digital tools in business-related and administrative systems in society, a high adoption rate of digital technologies among consumers, and the highest density of industrial robots globally, with 855 per 10 000 workers, which is about three times the OECD average (World Economic Forum, 2020[69]).

The Korean government has provided continuous policy support for the nationwide adoption of digital technologies. In the 2000s, the National Informatics Master Plan (2008-12) established "creating soft power", i.e. creating intangible assets, such as knowledge, technology and culture and "(building) innovative infrastructure for digital convergence" as two important pillars for Korea's transformation into an information society. In 2017, the Presidential Committee on the 4th Industrial Revolution (PCFIR) was established as a policy co-ordination body that develops comprehensive policy direction, strategy and action plans for ministries. More recently, in response to the COVID-19 pandemic, a wide range of immediate policy measures were rolled out to enhance the adoption of digital technologies by SMEs, notably the digital service voucher by the Ministry of SMEs and Start-ups (MSS), which subsides SME uptake of digital services with conditional grants to facilitate digital trade and strengthen cyber security (Bianchini and Kwon, 2021[11]). In the Digital New Deal, a major component of the Korean New Deal for the post-COVID-19 era announced in 2020, a total investment of USD 37.2 billion was budgeted until 2025, the majority of which is targeted at data networks and AI.

However, the pace of diffusion of digital technologies among Korean firms so far has been slow, particularly among SMEs. The digital divide is wide between large firms and SMEs, as in other OECD countries, but the gap tends to be wider in Korea compared to the OECD average (OECD, 2020[62]). For instance, as of 2018, the difference between large and small firms purchasing cloud computing services was around 31.1% (OECD average: 28.8%), and the difference in having performed big data analysis was 30.7% (OECD average: 22.5%). Korean firms are far behind OECD countries, with only 3% of small and 10.8% of large enterprises performing big data analysis (BDA) (United Kingdom: 13.3% for small and 35.4% for large firms; Germany: 12.9% and 33.9%, respectively).

As data-driven innovation is increasingly important within the digital transformation, Korean businesses have vast potential to benefit from user-related and firm-related data. Recent evidence shows that BDA significantly improves firms' innovation capacities in products, processes and organisation, with the highest impacts on productivity if combined with other ICTs, such as cloud computing (Gierten et al., 2021[79]). However, in Korea, the gap between large firms and SMEs in adopting sophisticated digital technologies, notably BDA, remains wide (Pak, 2021[80]). Moreover, Korean SMEs often lack awareness of the potential increase in productivity by digital systems and equipment as well as big data. The shortage of specialists who can help them with the introduction of digital technologies is a major problem. Korea shows the second-largest variation in training participation across firm sizes in the OECD (30% of micro-firms compared to 70% in large firms) (OECD, 2020[62]). However, Korea has undertaken numerous initiatives, e.g. network programmes connecting digitally advanced firms with SMEs, open data initiatives, including the "Data and AI-driven Economy Promotion Plan" (2019), as well as lifelong learning and vocational training programmes.

1.4.8. Recent support for the green transition could provide the momentum for major change

The green transition is a major challenge for the Korean business sector. In combatting climate change, Korea is under-performing, even with its swift introduction of the emission trading scheme (K-ETS) in 2015. GHG emissions per capita are among the highest in OECD countries and rose until 2018 (OECD, 2021[49]). Furthermore, Korea has the lowest ratio of renewables in its primary energy supply among all OECD countries. Korean companies exporting energy-intensive products may encounter significant decarbonisation challenges unless they decrease their carbon emissions soon, particularly in the face of potential carbon border taxes. This is especially true for the manufacturing and energy sectors, which contributed 37% and 36% of Korea's carbon emissions, respectively, in 2017 (Ministry of Environment Greenhouse Gas Inventory and Research Center, 2020[48]). Meanwhile, there is widespread awareness of global warming in Korea. In 2021, Korea's Ministry of Culture, Sports and Tourism conducted a survey, and of the 1 600 respondents, 96.3% responded that they perceived climate change as a severe problem. However, it remains to be seen whether the growing awareness of the climate crisis has been sufficiently translated into robust public support for the government's ambitious carbon neutrality target. Particularly, the rapid introduction of carbon reduction targets has been more or less perceived as a threat to companies' competitiveness and to employment in the manufacturing sector.

The green transition also presents opportunities for Korean businesses. Korea's climate strategy encompasses several broad objectives, including achieving carbon neutrality by 2050 and reducing GHG emissions 40% below 2018 levels by 2030. Climate change is not only a threat to energy-intensive legacy technologies but also presents opportunities to introduce innovative technologies that help reduce GHG emissions and meet the growing demand for low-carbon products and services. The recently announced Green New Deal sets ambitious goals for expanding the supply of electric and hydrogen vehicles. The provision of 1.13 million EVs, including passenger cars, buses, and freight vehicles, will be supported along with the installation of 45 000 chargers. The provision of 200 000 hydrogen vehicles, including passenger cars, buses and freight vehicles, will be supported along with the installation of 450 charging facilities. Some Korean companies have technological competencies and competitiveness, notably regarding solar panels and electric car batteries and reinforce their technology competency across different emerging green technologies. An "eco-ship" with high fuel efficiency and low pollutant emissions and a hydrogen-fuelled car have now become the world's number one products with a global market share of 65% and 55.2%, respectively.

1.4.9. Geopolitical tensions bear risks for Korean technology competitiveness

Uncertainty in global trade may harm Korean businesses in the longer term*.* A prolonged United States-China trade dispute could have a series of ramifications on Korean business and industry. In the short run, some Korean companies would benefit from US sanctions on Chinese high-tech goods. For example, Samsung's 5G network market share increased significantly after the start of the trade dispute, from 3.2% in 2017 to 23.3% in 2019 (KIEP, 2020[81]). However, eventually, this benefit is likely to fade as China's capabilities in advanced technologies strengthen despite pressures from the United States. In fact, China is not only closing the gap in advanced technology but advancing to the frontier, particularly in areas where Korea still has a comparative advantage, such as in semiconductors, batteries and displays. Furthermore, if the conflict between the United States and China intensifies, Korea will face increasing pressure from both sides. It will leave fewer policy choices for Korea, whose top two export markets are the United States and China.

Maintaining and enhancing technology competency in industry is essential. The United States-China trade dispute has implications for business entrepreneurs and policy makers in Korea. First, the importance of securing and maintaining technology competence for key and emerging industries cannot be overstated. For example, even after Japan sided with the United States, China took no retaliatory measures against Japan. China's imports from Japan even increased from USD 322 billion in 2017 to USD 344 billion in 2020 (KOTRA, 2020[82]). This is due to the robust competitiveness of Japanese products that cannot be easily replaced. Secondly, STI policy should be perceived and designed within a broader context, incorporating issues like supply chains, commerce, and national security. COVID-19 also exposed the disruption of global value chains. Third, diversification of international co-operation in STI and trade is important. In 2019, Korean firms' technology exports to the United States and China amounted to USD 2.59 billion and USD 2.55 billion, respectively and in total, technology exports to the two countries accounted for 37.4% of all technology exports (KOITA, 2022[83]). Korea is tightly integrated with the United States and China throughout the business innovation cycle. In order to reinforce its responsive capacities to external shocks, Korean businesses need to diversify their trade partners. At the same time, STI policy makers should broaden their perspective beyond these leading countries in order to build more diverse strategic international partnerships.

1.5. Production, circulation, and diffusion of knowledge for a new era of innovation in Korea

Compared to many other developed countries, Korean knowledge production – regarding resources, actors and outputs – has increased dramatically over a rather short period. As the knowledge production system has expanded, the roles of some of its key actors have also begun to change. GRIs, originally created to serve the needs of various strategic industries for technological development, now have to rethink their role, as several Korean firms have become technology leaders with advanced and substantial research capacities of their own. Universities have evolved from a purely teaching role to developing significant research activities, particularly with the emergence of the "IST"[21] universities. This implies that GRIs, higher education institutions (HEIs) and the government need to rethink their roles and identify pathways for ensuring that the Korean system for production, linkages and diffusion of knowledge is fit for purpose.

1.5.1. Defining features of Korean society that affect research and innovation policy

There is room for improvement in social capital, notably institutional trust, in order to advance towards innovation leadership and tackle transformation and societal challenges. Korea displays a high general awareness of government strategies, particularly R&I strategies. Nevertheless, trust in government institutions is low (also sometimes referred to as "institutional trust"), as confirmed by a recent OECD study (OECD/KDI, 2018[84]). The same source also confirms that "policy development and formulation in Korea may face low levels of transparency, lack of consistency, institutional competition between political parties and lack of internal collaboration." Such an overall lack of trust and weak social capital[22] partially explains the accountability and micro-management that characterise government S&T funding. There are also few independent academies and think tanks that stimulate, contribute to and curate public discourse and debate on the role of science and technology in Korea's development and societal and economic objectives.

Some past elements of Korea's S&T policy are now counter-productive to its current goal of innovation leadership and addressing societal challenges. These include detailed *ex ante* specifications and expectations for S&T projects, including technological objectives, goals or outcomes. Further, in the post-catch-up phase, where GRIs struggle to prove their value and find a clear purpose, there is a tendency towards mission drift, overlap and fragmentation as they attempt to position themselves in areas considered topical means to secure government funding. As explained in Chapter 4, The orchestration of this system could be made more effective, and the incentives should be enhanced for GRIs to collaborate among themselves or with academia or industry around clear strategic objectives.

1.5.2. Korea's higher education system is comprehensive, but its research performance could improve

HERD spending is below the OECD average and relies mostly on project-based funding. HERD represented 0.43% of GDP in Korea in 2020 (OECD, 2022[14]), a level comparable to Japan, the United Kingdom and the United States but below that of France and Germany.

Even though many universities perform research, few are true research universities. Among Korea's 430 HEIs, 85% perform R&D. HEIs employ 58% of PhD-level researchers in Korea. Most research done at universities is basic research, and most basic research in Korea is done at universities. Basic research was financed to the level of KRW 2 trillion (USD 1.7 billion) in 2020, with 75% from the MSIT and 25% from the Ministry of Education (MOE). This represents almost double the amount of 2017.

A few Korean universities benefit disproportionately from highly path-dependent advantages in terms of reputation, prestige, talent attraction and funding. There are different groups of universities: 1) institutes of technology under the purview of MSIT;[23] 2) national and public universities, which include flagship universities under the purview of MOE; 3) private universities. The five universities under the purview of MSIT and a handful of leading national universities, most notably Seoul National University, represent the top tier. A large gap separates them from the second-tier national and regional universities. This path dependency, combined with a rather limited exposure to international competition, stifles institutional dynamism and renewal, which seems to manifest itself in Korean universities' average rankings and research performance in terms of international comparison.

Korea has relatively few top-ranked institutions. Compared to countries such as Germany and Sweden, Korea has, in relation to population size, markedly fewer institutions among the top 200 universities in various university rankings, particularly the Shanghai and the Centre for Science and Technology Studies (CWTS) Leiden rankings, which assign more weight to research awards, publications in high-impact journals and citations. The Leiden ranking shows, for example, that only three universities[24] achieved 10% or more papers among the top 10% cited, while the others have 3-7% of publications among the top 10% cited.

1.5.3. The current funding structure for higher education institutions in Korea may limit growth

The dominance of project-based financing makes for limited autonomy and short-term focus. Some block funding for research has been introduced for universities under MSIT and recently also at national and public universities. However, a large part of funds still depends on project-based funding. Since priorities for this funding change with each election (five-year horizon), developing long-term research agendas and building large research teams is difficult.

Administrative processes create disincentives. The Korean government has made significant efforts to simplify administrative procedures and enhance research management autonomy, notably though the National Research and Development Innovation Act. Moreover, starting in 2022, the Integrated R&D Information System was put in place to comprehensively manage the information on research fund spending, investigators and research projects, with simplified and standardised templates. Nevertheless, it was noted during interviews with Korean stakeholders that researchers spend considerable time applying for and reporting to the government on research projects. There is still room to improve the degree of freedom for researchers to reorient research during the course of a project by encouraging researchers and project managers to utilise the new act. Similarly, investigators have to specify in advance which research equipment (valued above KRW 30 million) they intend to purchase. Meanwhile, it is encouraging that the National R&D Innovation Act, which took effect in June 2022, now enables investigators to adjust their purchases to changing circumstances or new needs. It remains to be seen if additional measures will be needed in the future. The government has made several efforts to increase the flexibility of research funding, the freedom of researchers and the institutional autonomy of universities. MOE and the Korean Council for University Education formed a task force in 2019 to tackle the issue of regulations on university operations to increase their autonomy. The National Research Foundation (NRF) has also implemented changes to make its funding more user-friendly and reduce the micro-management of research projects. However, changes in administrative culture – from a strong focus on short-term accountability, micro-management and nearsighted quantitative indicators of success to institutional autonomy, research freedom and long-term impact and breakthrough research – take time to develop (both in government and academia). They also require policy consistency and predictability. This is particularly the case in Korea, which does not have a longstanding tradition of strong and independent research universities. In this regard, the government should continue to strive to reduce the administrative burden for researchers regarding research funding and seek to increase researchers' freedom to change their research focus during the course of government-funded projects.

Research funding rules and reporting obligations for HEIs could be more flexible. While funding is relatively easily accessible and success rates for projects are quite high, researchers perceive difficulties in justifying deviation from the initial scope of research, as is often needed, particularly in basic research. The National R&D Innovation Act intends to ease funding rules for changes in research programmes and expenditures, which is a welcome change. However, the implementation of the law should be supported by adequate means, and it is too early to see the full effect of the law yet. As explained in Chapter 4, monitoring and performance measurement is focused on short-term, quantitative metrics (such as publications in leading journals and patents) rather than assessing and promoting ground-breaking research and long-term impact.

A specific incentive structure in at least one university provides for excellent performance. Ulsan National Institute of Science and Technology (UNIST) is one of the most successful universities on many metrics. For one, it has more than 13% of its publications among the top 10% cited[25] ones – the best result in Korea. In addition, they have 10-20% of their revenues from industry collaboration. This is the result of a specific, different incentive structure, whereby academics are incentivised to collaborate with industry (this directly impacts their salary), and the publications counted for their evaluation and promotion must be in the "top-cited" category. In addition, there is an incentive for international collaboration since invited talks at international events are required to obtain tenure at UNIST.

A rapidly ageing population is putting significant financial strain on many HEIs. Due to low fertility rates, the number of students is declining, marking a 13% decrease in enrolled students in 2020 compared to 2010. This, in turn, reduces tuition income and thus increases financial pressures on HEIs, in particular, less well-established ones. In 2015, the government implemented the Evaluation for University Consolidation Policy, where universities were assessed according to five grades. Institutions with lower grades reduced admission capacity and received limited financial support.

1.5.4. Korean universities can maximise their potential by collaborating internationally

International co-publications account for a smaller share of total publications than in a number of OECD countries and China. Furthermore, international co-publications, as a share of total publications, have increased more slowly than in countries such as Japan, Switzerland, the United Kingdom and the United States. Thus, there seems to be a difference between large Korean multinationals with a strong global market and innovation presence and research institutes and universities, which seem less international than their counterparts in many other OECD countries.

1.5.5. The role of public research institutes in Korea needs to be continuously redefined to match the changing needs of the economy and society

This sub-section discusses non-university research institutes that receive institutional (or "core" or "basic") funding from the state. It should be noted that outside of what would usually be considered as PRIs, MSIT manages five universities – the Korea Advanced Institute of Science and Technology (KAIST), the Gwangju Institute of Science and Technology (GIST), the Daegu Gyeongbuk Institute of Science and Technology (DGIST), UNIST and the University of Science and Technology (UST) – that are institutes of technology in the same sense as the Massachusetts Institute of Technology (MIT), namely research universities specialising in science and technology. They are formally regarded as GRIs but should rightly be regarded as universities since they account for a significant contribution to education and teaching. They do not form part of the analysis in this section.

PRIs seem to be misunderstood internationally for at least four reasons. First, PRIs tend to be discussed as a single category because the state owns them, while there are different PRI categories that have very different functions. These include government labs, scientific research institutes, RTOs and "technology centres" (see Chapter 4). Second, the role of some PRIs changes through the course of development, so if one compares countries at different stages of development, then similar-looking organisations turn out to be doing very different things. Third, different countries make different decisions about the division of labour between the university and institute sectors, so context is important in understanding PRIs. Fourth, there are (still) no coherent or internationally consistent statistics about PRIs.

1.5.6. The structure of the Korean public research institute system has been questioned but remains largely unchanged

Korea's PRI sector is a large part of the R&I system, accounting for 45.8% of Korean state spending on R&D in 2017 (KISTEP, 2018). The role of government labs has declined over time as their function was mostly split into two parts. Some of their more hard science and technological activities were moved into the GRIs under the NST, while the policy support functions have been moved into the NRC. Today, there are three groups:

- A group of 25 GRIs work in STEM disciplines with diverse roles and responsibilities, depending on their research strength and orientations. Some GRIs mainly support industry, while others attempt to tackle socio-economic strategic missions. It remains to be assessed whether the individual roles and responsibilities of the GRIs will be conducive to the overall national strategy for the innovation system.
- Technology centres promote industrial and business development within their own sector. Fourteen specialised production technology research institutes (SPTRIs) are governed by the Ministry of Trade, Industry and Energy (MOTIE) and provide testing, evaluation and process technology support, technology transfer services, notably from overseas sources, technological support, R&D projects and vocational training to SMEs in specific sectors, including electronics, automotive and photonics.
- A group of 26 government labs focus on policy research rather than on "hard" science and technology. These are today under the control of the Prime Minister's Office and organised under the NRC, which reports to the Ministries of Economics and Finance, Labour, Environment and Education and through those ministries to the Prime Minister's Office.

The original mission defined a broad scope for GRIs, ranging from basic through applied research and technology transfer to the industry. The first GRI – the Korea Institute of Science and Technology (KIST) – was set up based on the model of the Battelle Memorial Institute in the United States as an industrial technology centre to support industrialisation. It had a great deal of latitude to set its own strategy and experienced little micro-management from the government. Many of the other GRIs spanned off from it and were instrumental in acquiring, localising and transferring technologies in support of the highly successful catch-up industrial development in Korea. Over time, industry acquired strong capabilities in the higher technology readiness levels (TRLs),[26] and at the turn of the century, the mission drifted towards a stronger focus on basic and applied science rather than direct co-operation with industry.

In 1996, however, Korea's rapid industrial development and the growing technological capabilities of its large firms meant that the GRIs' role began to be questioned.[27] The role of the GRIs needed to change to adapt to Korea's stronger position and, particularly, to industry's higher technological capabilities. Accordingly, the government introduced a "project-based system" (PBS) of external, project-based funding, which was designed to promote competition between GRIs and led to the greater autonomy of principal investigators. This action slowed the growth of GRI institutional funding and introduced the incentive of competing for PBS funds. While principal investigators may now have greater autonomy in managing project progress and employing participating researchers, this has reduced their degree of autonomy under the Battelle model and, correspondingly, their ability to devise autonomous strategies. Namely, responding to PBS calls for proposals constrains researchers to topics defined in the calls rather than providing funding for developing long-term lines of research they deem important. While PBS was intended to align the work of the GRIs with higher-level R&I policies laid down at the government level, it also fragmented their work.

While some orientations for the GRIs from the *OECD Reviews of Innovation Policy: Korea 2009* were taken into account, many of them remain valid today. The 2009 review mentioned: 1) supporting technological development in SMEs; 2) moving away from industrially oriented R&D and towards public and welfare research; 3) concentrating on platform technologies; 4) leading Korea's shift towards more fundamental research; and 5) working in areas of interdisciplinary and fusion research. Some of these were taken into account; in particular, the government has made concerted efforts to raise the importance of fundamental research over the years, which is mostly backed by dedicated funding. The Institute of Basic Science (IBS) was founded in 2011 as a network of research centres modelled after Germany's Max Planck Society and Japan's RIKEN. The budget for basic research increased from KRW 1.2 trillion in 2020 to KRW 1.4 trillion in 2021 for individual researchers and to KRW 313 billion for research teams. In the recent Role and Responsibility reform, MSIT invited the GRIs to consult widely and consider how to revise their strategies in line with current needs. Several new themes suggested by the ministry are more societally oriented than before and are more technologically based.

However, several factors appear to have made it difficult for the GRIs to change course and enhance their orientation to industrial markets. The introduction of the PBS fragmented their work and tied them to policy priorities set at a higher level rather than increasing their market orientation. This trend is being gradually reversed. In 2021, institutional funding represented 41.5% of total funding, higher than before the introduction of PBS, according to MSIT data.[28] The role of GRIs in the national innovation system has become somewhat ambiguous. With the rising importance of universities, they have become less relevant to the big firms that have developed high levels of technological capability and look internationally for technology acquisition to complement their in-house R&D. The former GRI model of acquiring or developing new technologies and then transferring them to industry is now focusing on middle-level SMEs, which can make use of technology transferred in this way, but which lack the reach and resources themselves to acquire technology internationally.[29] For instance, KIST receives only 9% of its financing from private sector sources and has no ambition to increase it. It reset its official research direction to "creative and challenge-driven research". GRIs typically receive less than 10% of their funding from industry, in contrast to Europe, where it ranges from 30% to 70%, highlighting a weak connection between GRIs and industry, especially large conglomerates. Overall, their level of state funding – including institutional block funding plus PBS funding – remained very high, insulating them from the kind of market pressures RTOs experience in other countries.

GRI directors are formally appointed by the NST Council. They are elected by 17 NST board members, including 5 government officials. They are replaced after three or six years, depending on the evaluation of institutional performance. Paradoxically, this kind of instability at the leadership level, with constantly changing strategies and plans, risks promoting stability or path dependency within organisations, which become resilient to the desires of transient leaders. A lack of effective autonomy over spending, hiring, strategy, careers and equipment purchase, among others, has promoted path dependency. Although PBS was introduced to promote competition among PRIs, it would be useful to introduce a holistic government strategy for reforming the PRIs to adapt their roles to current needs. Recently, the individual GRIs revised their own roles and responsibilities, but the concern remains whether their individual roles will be conducive to and aligned with the national strategy for innovation. The recent provision by NST of “convergence funding” intended to promote co-operation between GRIs and between research areas to address complex socio-economic issues involves small sums of money. Since 2014, the evaluation of GRIs under NST is customised for each institution, which sets its own qualitative and quantitative objectives. However, it is not yet clear whether this has helped address the societal mission of the GRIs – which was historically to support industrial development, evolving towards addressing societal challenges. It is also unclear whether the incentives are aligned and whether the co-production of capacity and technology needed to help companies develop is encouraged. In 2019, the government specified within its National R&D Performance Evaluation Implementation Plan that for performance evaluation of research institutes, a minimum of 60% of criteria should be qualitative, marking a shift away from the previously strong focus on quantitative measures, such as scientific publications and papers.

The Korean PRI system, more broadly, is relatively fragmented. This holds true, particularly when compared with other countries, where institutes have tended to become more polytechnic and, therefore, better able to work with a range of customers in different branches, technologies and markets. To address this issue, the MSIT made changes to the governance of the NST and adjusted the function of individual GRIs to avoid duplicating functions across organisations. For example, GRIs commonly support SME development, but research fields and targets are differentiated based on each GRI’s roles and responsibilities.

Evidence from other countries suggests a growing need for interplay between university and institute research for two reasons. First, as the level of development rises, so industry (and other user sectors) needs increasing access to more fundamental developments in knowledge. Second, more generally, the amount of scientific knowledge necessary to keep pace with advancing technology is increasing. However, there is little evidence of the Korean institute and university sectors co-operating more closely via collaborative research, joint appointments and joint PhD supervision, as seen elsewhere, for example, among the Fraunhofer institutes in Germany or the RISE institutes in Sweden.

1.5.7. Investment in research infrastructures is good, but more awareness is needed

The Korean government has invested significant resources in national large research infrastructures, with positive effects. The government set up two roadmaps to strengthen Korea’s lead position in science and technology and its creative economy. Large research infrastructures contribute significantly to domestic and international co-operation, attracting foreign talent and promoting knowledge exchange. Korean participation in international research infrastructures such as CERN and the European Molecular Biology Laboratory (EMBL) further underscores the government’s awareness of such activities' positive effects.

Investments have caught up with other leading innovation countries but still lag other innovation leaders. Korea has earmarked around 0.27% of GDP as part of its two National Large Research Facilities Roadmaps, which is a combined investment on par with the United States (0.28%) but below that of Japan (0.48%), the European Union (0.37%) and China (0.33%).

Although policy makers are highly aware of the potential and benefits of research infrastructures, this awareness needs to be promoted at the institutional level. While the various adopted roadmaps and initiatives and their increased funding reflect strong progress and awareness of the need for research infrastructures, on the practical level, the co-utilisation of equipment, for instance, remains rather low. University professors are often not aware and/or are not incentivised to make their research equipment available to other scientists. This may be due to factors such as a potential lack of awareness, low recognition, absence of plans for shared use of equipment or accounting issues.

1.5.8. Knowledge flows between higher education, GRIs and business have room for improvement

GRIs were set up in the 1960s as RTOs with the primary goal of transferring technology to the Korean private sector. This initiative was largely successful, and today, Korea's large companies are autonomous with huge R&D budgets (Samsung spent around KRW 21.2 trillion in 2021, comparable to the entire government of KRW 27.4 trillion). However, today, the positioning of GRIs varies, with some working closely with industry while others (such as ETRI) compete against it. In general, private co-financing of GRIs is quite low (around 10%), and GRIs are not striving to increase it.

Knowledge flows from universities and GRIs to industry, traditionally limited in Korea, have increased since the turn of the millennium. Diverse policy measures are being used to facilitate the commercialisation of public research results. For example, the Innovative Product Public Procurement Pre-validation system helped the market launch of R&D outcomes that were having difficulty in commercialising; the Public Technology Commercialisation Fund increased investments in the commercialisation of basic research outcomes; and the Public Research Result Use Promotion R&D Project supported the technological advancement needed for linking outstanding public research results and market demands. Between 2011 and 2019, technology transfer cases more than doubled, from 5 193 to 11 676, with a relatively even split between GRIs and HEIs.It is important to note, however, that formal technology transfer based on patents and licensing is normally only a small part of the wider pattern of knowledge exchange among institutes, universities, industry and civil society.

Enhanced by governmental subsidies, collaborative research projects between universities and firms are also increasing, but there is potential to increase the quality and scope of knowledge transfer through research collaborations. Practices and performance indicators in the GRI sector continue to focus on technology transfer via the sale or licensing of intellectual property rather than the co-production of innovation. Industry appointments by researchers at national universities are not allowed. Research university faculty and GRI research staff are incentivised to focus on publication in academic journals instead of engaging in industry collaborations, for which they receive limited institutional support and recognition. Large conglomerates sometimes collaborate with leading research universities in Korea but tend to prefer to collaborate with leading universities in western countries when developing fundamental technologies. Many university-industry research collaborations are conducted between non-research universities and SMEs and tend to be short-term and small-scale.

Inter-organisational knowledge co-creation and knowledge flows have increased between leading research universities, GRIs and private sector companies in recent years. This development appears to have been driven by the enhanced research capabilities of leading universities and the lower cost for companies when using subsidised on-campus collaborative research facilities. There are also now some major research consortia that include university, GRI and private sector company partners. However, these positive changes appear to be mostly concentrated in specific departments of universities and GRIs with relatively abundant resources and strong research capabilities. Most university faculty and GRI researchers are still not interested in engaging with industry.

Academia-industry collaboration today is below potential. The number of co-publications between industry and academia has been decreasing over the last decade,[30] and private sector co-financing remains confidential, with only a few projects co-financed by the conglomerates at the top universities, such as Seoul National University, KAIST and UNIST, and projects financed by the Samsung Foundation, which pledged USD 1.5 billion for research.

Multiple barriers to collaboration persist, and they vary across different actors. From the research side, the main hurdles are: 1) high pressure on academics for publications, which precludes them from working on more pragmatic industry-relevant projects that are less likely to produce sufficient publications; 2) easy availability of project-based funding, which reduces incentives to develop more demanding projects with industry; and 3) researchers' personal objectives that do not take into account industry collaboration. From the large business side, there are also significant barriers, including a perception of academics as being too slow and disconnected from business needs and as having a preference for keeping most research in-house, made possible through sufficient internal resources (somewhat at odds with international practices that favour more collaboration with academia). Finally, these firms share the feeling that basic research is better addressed by academia outside Korea, to which the conglomerates have easy access through their global networks (even though Samsung does have a significant number of co-publications with Korean academia).

Collaboration between GRIs and industry is burdened by legacy. Since the 2000s, the practices and performance indicators in the GRI sector have continued to focus on technology transfer via the sale or licensing of intellectual property rather than the co-production of innovation. Having noted the limitations of such linear models of knowledge diffusion promotion, in 2014, the NST started the Joint Technology Licensing Office (TLO) Promotion programme (KRW 15.9 billion for 2014-19) that aimed to shift the focus to the "demand-pull" approach and to better monitor the use of transferred technologies by companies.[31] In parallel, technology-holding companies, such as ETRI Holdings[32] in 2010 and Korea Science and Technology Holdings (KST) in 2013,[33] were established to promote the transfer of technologies. Nevertheless, challenges remain since industry collaboration is generally far from the focus of their mission (defined by their roles and responsibilities), which is largely determined by the heads of organisations. Government support is largely considered insufficient. Also, GRI research staff is incentivised to focus on publication in academic journals instead of engaging in industry collaborations, for which they receive limited institutional support and recognition.

Research universities are a relatively recent concept in Korea, and only a few have the capability to meet the knowledge demands of world-leading companies, compete with top international academic institutions and generate a substantial number of start-ups/spin-offs. These include mostly the universities under MSIT mentioned above and a few national universities, such as Seoul National University. Faculty do not have sufficient incentives to create spin-offs, and entrepreneurship occurs mainly among students and sometimes as a retirement option.

Regional universities provide R&D support to SMEs, but such co-operation could be better structured. Co-operation occurs on demand from an SME when it formulates a need. The university responds and performs the research only if the SME gets project-based government financing. A more proactive approach is that of manufacturing extension services, which is embodied through the SPTRIs to a certain degree.

Infrastructure for linkages and co-creation could be further developed. Korea has 5 innopolises and 12 innotowns that aim to promote technology commercialisation in PRIs based on regional needs. It also has 19 science and technoparks focused on fostering local industries and Creative Economy Innovation Centres (CCEI) on start-ups. Concurrently, in many OECD countries, comprehensive infrastructure is being systematically developed to provide office and laboratory space, along with services such as dust-free labs, supercomputing platforms, and consulting in areas such as strategy, marketing, intellectual property, legal, and human resources, to foster the creation of "deep tech" start-ups. Examples of such infrastructure include the EPFL (École Polytechnique Fédérale de Lausanne) Innovation Park in Switzerland, as well as competence or excellence centres for public-private co-operation on projects and programmes. Even though Korean innopolises have been successful in grouping research institutes, research activities and innovative companies, the development of linkages has been less successful than, for example, in the San Diego biotechnology cluster, due to insufficient networking activities (Kim and An, 2012[65]). The original innopolises were considered too big (more than 40 organisations) to generate significant synergies, and this is why much smaller innotowns were created in 2019, designed to be "small but robust R&D zones", run by the regional government and focusing on stakeholders from universities, GRIs and businesses with high innovation potential in a limited zone to prevent excessive geographical spread.

Policy instruments in favour of linkages rely on the classical technology transfer paradigm rather than co-creation. All universities and GRIs have technology-licensing offices, but the licensing revenue generated is relatively limited, which is unsurprising in a "technology push" mode. Korea has developed innovation vouchers of relatively high unit value, but matching grants between academia and industry are not very common. Many OECD countries opt for a large number of low-value vouchers, which act as "spreading pollen", creating incentives for a large number of seed collaborations to take place and overcome the barrier of starting collaboration between SMEs and academia. On the other hand, there are already a number of events designed to bring together the communities and raise awareness about each other's needs, the biggest being the University-Industry Collaboration (UIC) expo held jointly by MSIT, MOTIE and MOE. At universities, the spread of the "third mission", where collaboration with industry becomes an official mission at the same level as teaching and research, seems limited.

1.6. STI governance for a new era of innovation in Korea

Since the 1960s, the Korean government has played a key role in setting favourable framework conditions and, more importantly, steering and sequencing the development of Korea from an agrarian to a dynamic industrial economy. Following the development of the STI system via numerous reforms, the development of the Korean STI structure is currently led by three imperatives:

- streamline and better integrate the expanding governance system to reduce well-acknowledged problems of co-ordination (overlaps between ministries' R&D programmes, conflicting priorities, difficulty allocating a vastly increasing R&D budget, etc.)
- reframe policies, organisations and programmes away from catch-up and towards supporting Korea's new position as an innovation leader in some sectors
- implement directional and holistic policies to tackle the societal challenges faced by all advanced and developing countries.

These three imperatives have important implications for the way Korea sets strategic orientation to the system, ensures the necessary co-ordination to align actors' plans and resources, and co-operates across the government.

1.6.1. A comprehensive STI governance system

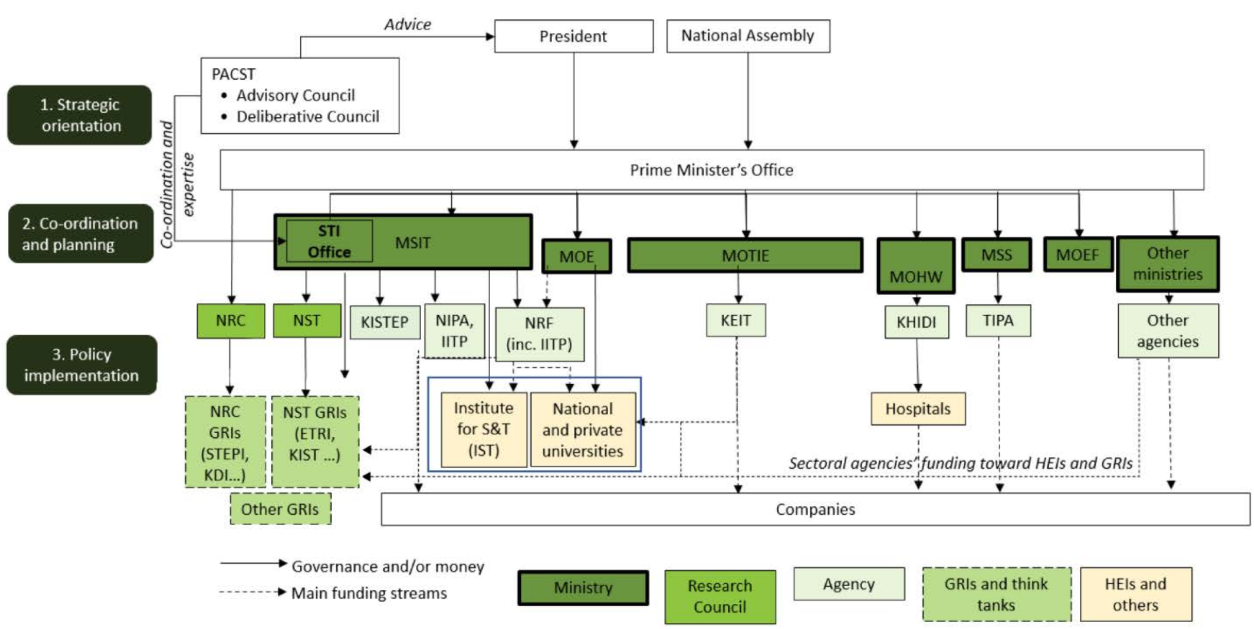
The STI governance system was initiated by the Framework Act on Science and Technology in 2001 and continuously refined over the past decades. Since 2001, the act has been amended several times and implemented through a proliferation of new or reformed funding bodies, laws, regulations and programmes. A major step in streamlining the STI system was enacting the National R&D Innovation Act of 2021 to rein in and simplify its governance. There have also been attempts to merge or reorganise certain institutions to improve co-ordination and/or streamline the structure.

Efforts to adjust to new priorities on a five-year cycle provide the flexibility to adapt STI policy to changing government priorities but can result in a significant discontinuity in the R&I governance and funding system. Achieving consistency between the political agenda and R&I policy is not always possible. However, many successful systems manage to establish at least a high-level consensus across the political spectrum about the priorities of R&I policy and the need for a set of organisations that is stable or evolves relatively slowly. Shifting priorities makes it challenging to establish the necessary trust in government orientations to promote ambitious R&D investment, particularly in addressing societal challenges that require greater reliance on public funding and longer-term commitments to develop the necessary expertise and infrastructure.

Like several other countries, Korea has demonstrated a significant level of responsiveness when confronted with crises, such as the COVID-19 pandemic or the Japan-Korea trade dispute in 2019, in order to mobilise STI communities. Specific action plans, strategies and committees were formed to ensure an effective and co-ordinated response.

1. **Korea has a well-established three-tier governance structure typical of advanced countries.** The Korean STI system has three main levels of governance, composed of dedicated institutions with clear legal mandates to perform the essential functions necessary to steer, co-ordinate and implement STI policies (Figure 1.2).
2. **Strategic orientation:** the level of the executive and legislative branches of government and the advice provided to them.
3. **Co-ordination and planning:** the level of the individual ministries or “administrations”.
4. **Policy implementation:** the level of funding agencies (also known as intermediary or management agencies) which implement and evaluate policy on behalf of the ministries.

Figure 1.2. Korea’s STI governance structure



Note: Full names of institutions here in descending order: Presidential Advisory Council on Science and Technology (PACST), Ministry of Science and ICT (MSIT), Ministry of Education (MOE), Ministry of Trade, Industry and Energy (MOTIE), Ministry of Health and Welfare (MOHW), Ministry of SMEs and Start-ups (MSS), Ministry of Oceans and Fisheries (MOF), National Research Council for Economics, Humanities and Social Sciences (NRC), National Research Council for Science and Technology (NST), National IT Industry and Promotion Agency (NIPA), Institute of Information and Communications Technology Planning and Evaluation (IITP), Korea Association for ICT Promotion (KAIT), National Research Foundation (NRF), Korea Evaluation Institute of Industrial Technology (KEIT), Korea Health Industry Development Institute (KHIDI), Korea Technology and Information Promotion Agency for SMEs (TIPA), Korea Institute of S&T Evaluation and Planning (KISTEP), Korea Institute for Industrial Economics and Trade (KIET), Korea Institute of Marine Science Technology Promotion (KIMST).
Source: OECD based on desk research and stakeholder interviews.

1.6.2. The role of the S&T Basic Plans in a fragmented STI landscape

In the Korean system, the high-level orientations are set in the programme outlined by the newly elected President and used as the basis for developing the five-year Science and Technology Basic

Plan (hereafter, the "Basic Plan"). This overarching document, reflected in and complemented by area-specific strategies and plans, has driven and provided legitimacy for some important changes in the past. This is evidenced in the turn to a post-catch-up STI system with a strong increase in basic research funding, related reforms, and proactive measures taken to support the emergence of new industries (e.g. the biotechnology sector).

The Basic Plans are structured along broad strategic directions increasingly focused on solving societal issues, in line with the overall vision to build a more human-centric STI system. These wide orientations are complemented by more concrete programmes with clearly assigned responsible ministries. The 5th Basic Plan announced in 2022, covers 2023-27 in response to national societal challenges, such as technological hegemony, supply chain issues, climate change, the digital transition and low birth rates. As for previous Basic Plans, each broad strategic thrust includes more precise implementation programmes, action initiatives and a list of 12 critical technology areas and 50 core technologies that will receive specific support. The 5th Basic Plan also indicates targets for some important indicators, such as the share of top-1% cited papers (set at 4.8% for 2022-26, up from 3.53% in 2015-19).

The Basic Plan is developed through an elaborate multi-stakeholder process that aims to cut across sectoral, disciplinary and bureaucratic silos. During the development, each strategic thrust is governed by dedicated committees and sub-committees gathering experts and stakeholders, including decision makers from different parts of the government. Furthermore, the Basic Plan's development includes analysing and considering over 90 medium- to long-term strategies from different ministries.

The Basic Plan development process follows different stages of foresight and technology forecasting, consultation and concertation with a broad range of communities. The cycles of S&T foresight and Basic Plans are aligned, and a formal procedure, starting two years before the launch of the Basic Plan, connects the two processes. The Korea Institute of S&T Evaluation and Planning (KISTEP) plays a key role in supporting the government in terms of technology assessment, foresight and S&T planning. Although the foresight exercises increasingly take into account societal aspects, the exercise remains centred on technology forecasting and culminates in a set of technological guidelines. More generally, various research institutions (in particular KISTEP and the Science and Technology Policy Institute [STEPI]) provide strategic intelligence on science, research and innovation through foresight, planning and evaluation work. GRIs under the NRC (e.g. Korea Development Institute [KDI], Korea Environment Institute [KEI] and STEPI) are instrumental in providing various types of analytical support for STI strategy development, policy making and evaluation in their respective areas. Several have kept close links with the sectoral ministries they were created to support in the 1980s or 1990s.

Taking into account the orientations set in the Basic Plan, several ministries also develop their mid-term strategies and plans, often with support from sectoral or cross-sectoral advisory committees. While the Basic Plan is meant to be the strategic document with the highest-level authority in the area of science and technology, important strategies include those set by MOTIE to guide business innovation (e.g. the Industry Technology Promotion Plan and the Industry Convergence Basic Plan). Other plans provide strategic guidelines for R&D in energy, transport and agriculture, among others. Some plans (such as the one from the Ministry of Land, Infrastructure and Transport [MOLIT]) have a ten-year horizon and are revised every five years. Other plans, such as the Agricultural, Food, Science and Technology Comprehensive Development Plan of the Ministry of Agriculture Food and Rural Affairs, have a five-year timespan.

The Framework Act on Science and Technology includes a formal and comprehensive process for monitoring the implementation of the Basic Plan on both a mid-term (five years) and an annual basis. Each ministry submits a mid-term action plan to the STI Office within MSIT that provides an overview of the new and ongoing programmes and activities to be implemented in the coming five years. The MSIT is tasked with reviewing these mid-term plans, notably to check whether they align with the Basic Plan and do not overlap with other ministries' plans. Each year, the sectoral ministries and agencies also report to the STI Office about actions undertaken in the different strategic thrusts of the Basic Plan and the main outcomes of these actions. The STI Office integrates these reports in an annual Basic Plan implementation plan submitted for review to the Deliberative Council of the PACST, the highest STI advisory and co-ordination body in Korea, chaired by the President of Korea.

At the end of the review process, the MSIT delivers a list of recommendations that may require the ministries to amend their plans and/or should be taken into account in their annual action plans. However, this monitoring does not seem to result in significant changes, and its influence on ministries' policies remains unclear, in practice, beyond MSIT programmes. Despite the different centralised processes for ensuring the alignment of the Basic Plan and sectoral plans, ministries keep a high level of strategic autonomy, which has usually led to new processes for additional supervision and monitoring.

Against this backdrop, there seems to be little space for strategic and systemic discussion among ministries between a strategic orientation process every five years that is too generic and a budgeting process that focuses each year on a multitude of specific programmes.

The first five-year R&D Investment Strategy delivered by the STI Office in 2023 is an important new step to better bridge the S&T Basic Plan and the sectoral ministries' mid-term plans. The objective of this document is to be the "missing link" between mid-term overall strategic orientations and annual sectoral planning. It is too early to assess the added value of this new process.

PACST's Advisory Council is the highest-level body that validates the different processes at key milestones. They also host relevant policy discussions among experts to advise the President, which can prove useful on specific policy issues. However, it is not playing a more systematic role in generating mid- to long-term policy. PACST's Deliberative Council plays a comprehensive role at different stages of the policy cycle, from aligning strategies and sectoral five-year plans to reviewing action plans and monitoring reports and yearly programme proposals. The STI Office supports these councils, leads the development of the Basic Plan, and reviews the ministerial plans, which is discussed in the setting of the Ministerial Conference as well.

Based on the directions set in the Basic Plan and the mid- to long-term investment strategy, more detailed holistic strategic orientations are provided at the programming level during the annual planning and budgeting process. This tends to result in the strategic orientation being overrun by short-term administrative imperatives, information overload, low-level budget competition and inter-ministerial turf battles.

1.6.3. Sophisticated mechanisms for cross-ministerial co-ordination of STI budgets are prevalent, but processes could be more efficient

A sophisticated process is in place to set the overall R&D budget, allocate it among the different ministries according to their plans for activities during the year, and co-ordinate these plans to increase strategic consistency and avoid unnecessary overlaps. The plans and programmes from about 26 ministries and departments (900 programmes in 2020) are submitted to the STI Office, which reviews them with support from the Deliberative Council, 8 sub-committees of about 15 scientific and technological experts from the public and private sectors, in specific areas (energy, ICT and convergence technologies, etc.). These experts assess the technical soundness and feasibility of the different R&D programmes submitted by the ministries. The assessments are supplemented by the STI Office's analysis of the consistency of the different programmes between themselves and with the priorities of the Basic Plan.

In addition to co-ordinating within the annual budgetary process, the ministers from the eight ministries with the highest spending regularly convene in the Ministerial Conference of Science and Technology to exchange information and discuss their plans and programmes. These meetings, held about once a month, allow for more lively and frank discussions about challenges and new initiatives than in more formal committee settings.

Despite this elaborate, systematic and centralised process for co-ordinating STI plans and programmes, insufficient inter-ministerial co-ordination remains one of the key issues hindering the effectiveness and efficiency of STI policy. A survey carried out by STEPI regarding the relevance of the diagnosis and level of implementation of the recommendations of the 2009 and 2014 *OECD Reviews of Innovation Policy* for Korea shows a high level of consensus on the need to improve policy co-ordination across ministerial and agency silos. It is one of the recommendations that has been the least implemented. It comes second in terms of importance for Korea's present and future (of all 2009 and 2014 review recommendations). The many stakeholders consulted during the review exercise, within the government and in performing organisations, fully support the results of this survey.

The annual budgeting process provides a unique mechanism for a holistic review of the budget requests of 26 ministries, but it is labour-intensive and results in only minor adjustments to programmes. This process mobilises significant human resources within ministries, at the STI Office, among experts of the Deliberative Council and at the MOEF. Furthermore, there are rarely significant changes to the content of programmes, the merger of programmes or the reshuffling of projects among programmes. The process intervenes mainly on budget requests. According to the STI Office, the process resulted in significant efficiency gains, representing about 9.3% of the overall 2023 R&D budget, as it avoided important overlaps. Another significant added value of this process is that the sectoral ministries interact with STI-specific organisations (the STI Office and the Deliberative Council) with expertise in this policy field, while in most other countries, the finance authorities keep their main budgetary prerogatives. The need for specific research and innovation expertise was one of the main reasons for the delegation of the budget formation function to the STI Office and Deliberative Council in the first place.

The annual budgetary review of ministries' proposals operates at a granular level of R&D programmes, which insufficiently feeds into higher-level, more systemic, strategic discussions. The reasons for implementing such a process are deeply entrenched in Korean bureaucracy on various levels. Overall, the MSIT can only intervene within the budgetary limits set for each ministry by MOEF, therefore, through the adjustment of programmes and projects. The "meso" level of policies and groups of programmes, essential to linking the large strategic orientations and the activities implemented in projects and other types of initiatives, seems to be overlooked in Korea. Against this backdrop, larger strategic entities are often used as an "umbrella" for smaller-scale programmes.

Another key potential issue is the sustainability of this process of centralised annual review of programmes. While in 2003, this process involved the review of 234 R&D programmes submitted by 19 ministries and agencies, with 142 civilian experts joining the review process, 949, 1 198 and 1 254 programmes were reviewed, respectively, in 2020, 2021 and 2022. This increase in the number of programmes to be reviewed might, in the future, consume an unsustainable amount of resources and/or lead to a procedural mechanism with less value. It is essential to preserve resources for actions of the STI Office at a more systemic and strategic level, in close interaction with sectoral ministries. The already mentioned new five-year R&D Investment Plan aims to strengthen the strategic aspect of budgeting. Reviewing whether this new mechanism has had the intended effect will be important.

Overall, policy making seems overly focused on the process of allocating resources and managing ministries' budgetary competition, whereby arising problems and emerging priorities are addressed by reallocating and reshuffling funding rather than developing a coherent and holistic R&I policy.

1.6.4. Cross-agency co-operation in R&D programme implementation is limited, although reforms have been made

STI policies are mainly implemented in the form of multi-annual R&D programmes by several management agencies, with elaborate programme management procedures throughout the whole project cycle. The National R&D Innovation Act of 2020 includes new provisions for regular reviews of agencies by their respective “principal”. As in all advanced countries, these agencies are tasked with defining the precise programmes with their line ministries. They have well-established processes for performing a variety of tasks (development of roadmaps, calls for proposals, consultation with various experts and stakeholders, monitoring and evaluation). Within agencies, Programme Directors are important actors responsible for consultation with stakeholders and managing the portfolio of projects in their respective areas.

Agencies are funded quasi-exclusively by their line ministries, which steer and evaluate them. Co-operation between agencies remains infrequent and often limited to a division of work in large inter-ministerial programmes. Large programmes are one of the main mechanisms for collaboration among ministries and agencies across policy silos. However, these programmes often take the form of umbrellas to host the numerous small projects of different ministries managed by their own implementation agencies. They therefore often replicate the vertically segmented structure between policy fields, with exclusive relationships between ministries and their respective agencies in each silo. Therefore, the added value of these programmes lies in the *ex ante* division of tasks among the participating ministries, which avoids unnecessary overlaps and some integrated monitoring of the programmes. While this undoubtedly raises the efficiency of these large-scale programmes, it falls short of more co-operative practices and joint actions where integrated teams belonging to different agencies collaborate to select, manage and evaluate projects.

1.6.5. The monitoring and evaluation of programmes and projects has significantly changed, but it is too early to assess the effects of the reforms

The pre-feasibility test that conditions the launch of large programmes can, in principle, prove beneficial to avoid misuse of considerable budgets. The criteria for reviewing these large programmes have been modified to be better suited for different profiles of R&D projects. The mechanism seems to have several objectives, including the imperatives to reduce budgetary expenses, increase programme effectiveness and better align them with overall priorities.

The difficulty in passing the feasibility test may create opportunity costs and lead to avoidance strategies. Several ministries reduce the size of their projects or split them into several programmes in order to not exceed the KRW 50 billion threshold. This can result in increased transaction and management costs and possibly in reduced effectiveness of sub-scale programmes. It also worsens the issue of the fragmentation of the STI landscape in smaller programmes and projects without sufficient attention to wider systemic issues or needs. The MSIT has recognised this issue and plans to raise the threshold to KRW 100 billion. This process should be reviewed in one year to assess the result of this change and, more generally, its overall added value and unintended effects.

The monitoring and evaluation of programmes and projects is framed by a system of laws, guidelines and procedures that has evolved significantly since the adoption of the performance-based system in 1996 and the performance management system in 2003. Many reforms have been enacted, but the system's limitations persisted. Monitoring and evaluation continued to focus unduly on the project level and to treat *ex post* evaluation more as a test of project execution than as a tool for understanding goal achievement and learning lessons at the programme and policy levels. In particular, monitoring and evaluation both focus on short-term inputs and outputs (publications, patents, licensing income, etc.).

The 2005 Research Performance Evaluation Act was significantly revised in 2021 to alleviate some key issues. Importantly, the autonomy and responsibility of sectoral ministries for programme and project evaluation were strengthened. For the sake of transparency, ministries were also asked to develop an evaluation strategy plan and to evaluate this evaluation strategy plan. Another change, in continuation of previous reforms, consisted of promoting research quality and using evaluation criteria rather than indicators focused on the quantity of outputs. Finally, the STI Office performs a new "impact-chasing" evaluation five years after the end of selected projects to assess a broader range of impacts, including societal ones. It is too early to assess the effect of this recent reform.

1.6.6. Overarching strategic framework for Korea's sustainable transition

In line with the President's commitment to combatting climate change, the government proposed in October 2020 to achieve carbon neutrality by 2050. This recent commitment remains to be confirmed in years to come, as difficult trade-offs, with potentially significant economic and social consequences, will have to be made. The challenge is considerable as Korea starts from a high level of emissions.

The government launched comprehensive policy plans and programmes to turn these commitments into action. The Committee on Carbon Neutrality is a specific body established in May 2021 to serve as the "control tower" of all carbon neutrality policies in the country (the Net Zero Policy Framework) and as a platform for citizen consultation and engagement. The Korean New Deal, announced in July 2020 and revised since then, consists of three main pillars: the Digital New Deal, the Green New Deal and the Stronger Safety Net, along with measures to support regional development. In 2021, upon reassessing the recent changes in domestic and external environments and their impact on Korean society, the government rebranded the initiative as Korean New Deal 2.0. Some of the policy areas were redefined and expanded, and, for instance, "building a policy framework for carbon neutrality" was newly introduced under the green transition initiatives.

While these new initiatives, their high-level governance and considerable budgets are significant steps, it is unclear whether they represent a qualitative shift from traditional strategy and modes of intervention. The governance structure needs to be clarified and streamlined as there is a profusion of committees active in the areas of carbon neutrality, notably those established to co-ordinate the Net Zero Policy Framework and the Green New Deal. It is also unclear whether this programme represents more than a new source of funding. It is essentially an umbrella for ten large programmes with rather short-term objectives implemented by different ministries. Furthermore, the Green New Deal seems to be focused on achieving economic recovery through new activities in the green area.

Korea has demonstrated a strong interest in technology-focused, mission-oriented innovation policies in the past three to four years, actively engaging in the work of the OECD on this policy approach and experimenting with three schemes: the Innovation and Challenge Projects by MSIT; the Alchemist by MOTIE; and the Future Challenge Technology Development Programme by the Ministry of Defence.

These initiatives are too recent to be assessed. However, these belong to the type of "DARPA-like" challenge-led schemes. These tend to be focused on research and technology outcomes, and their success will depend on their ability to be coupled with public procurement instruments or some other dependable source of demand, as is the case in the United States and Nordic countries (e.g. Norway's Pilot-E scheme). These initiatives can be effective in accelerating technical changes in some targeted areas but fall short of supporting more systemic innovation that links technological, behavioural, regulatory, social and market innovation. The characteristics of the Korean programmes are consistent with their main objective, which is to strengthen national competitiveness. The mobilisation of this policy approach to support the green transition will require a different type of design and governance. Some recent announcements propose to follow this route but have not yet been enacted.

1.7. SWOT analysis of Korea's innovation system

Table 1.1. SWOT analysis of Korea's innovation system

<table>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>
Framework conditions for innovation

Korea's STI policy is strongly committed to and agile in adopting international best practices.
Entrepreneurs benefit from macroeconomic stability, high-quality infrastructure and ease in starting a business.
Progress has been made in trade and investment openness, and few restrictions remain in the manufacturing sector.

Industrial dynamics and business innovation

Korea has a highly competitive industrial and manufacturing base, notably in (high-end) electronics, automotive, communications, shipbuilding and petrochemicals.
Leading conglomerates are well integrated into domestic and global value chains and are strongly export-oriented with growing global market share.
Korea has excellent ICT infrastructure, high adoption rates of some digital technologies among consumers and large firms, and the highest robot density in industry.
Korea has world-leading levels and growth of business innovation research spending.
Strong governmental support for SMEs and early-stage entrepreneurship results in a rapidly growing start-up scene.

Research institutes and higher education

Korea has a strong higher education system with the highest ratio of tertiary graduates worldwide, many of whom are in STEM disciplines.
Korea boasts high and growing expenditure for research in government research institutes and higher education institutions.

Governance and initiatives to tackle societal challenges

Korea's strong foresight system systematically informs the whole of government and sectoral strategies and plans.
Korea has a comprehensive, five-year, overarching strategic framework to guide STI activities, informed by foresight and comprehensive consultations.
Korea has a central STI co-ordination unit ("control tower") with a powerful mandate to co-ordinate STI-related plans and activities of about 26 ministries who intervene in this area.

</td><td>
Framework conditions for innovation

Korea has had longstanding difficulty transitioning from being a "fast follower" into a leader in science, technology and innovation.
Koreans show risk aversion when launching new initiatives (including initiating high-risk research).
Cultural openness towards foreigners, which could bring new stimuli and creative ideas, is not very pronounced in Korea.

Industrial dynamics and business innovation

There is limited contribution of knowledge-intensive services to the economy as services are concentrated in lower value-added sectors.
There are restrictions on foreign investment in services, including communications.
There are large gaps in society and duality in labour markets, particularly regarding SME/chaebol, rural/urban and old/young divides.
Many SMEs have a low absorptive capacity for new technologies due to difficulty raising digital and technical skill levels and attracting talent, leading to a wide productivity gap with large firms.
Low business R&D expenditure in the service sector leads to slow development of high-value-added services and exports of such services, including royalties and license fees, financial services, miscellaneous business services and IT services.

Research institutes and higher education

Strong reliance on the government-funded project-based system fosters short-term focus, fragmentation and a lack of market orientation in research.
There is a low share of high-impact and high-visibility research.
Korea has a modest performance on international higher education rankings.

Governance and initiatives to tackle societal challenges

Resource-intensive and rather mechanistic co-ordination leads to inflexibility, slow action, and the production and sharing of excessive amounts of centralised information.
There is insufficient co-operation and reduction of ministerial silos within large inter-ministerial programmes and initiatives (including the Green New Deal).

</td></tr>
<tr><th>Opportunities</th><th>Threats</th></tr>
<tr><td>
Industrial dynamics and business innovation

Korea's large and innovative firms are well-positioned to shape and lead the international innovation frontier in upcoming technological transitions as part of the 4th industrial revolution.
Despite being relatively restricted in trade and investment, particularly regarding services, Korea has shown strong progress since its accession to the OECD. Further reducing remaining barriers may result in job creation, knowledge transfer and, therefore, enhanced innovation and productivity growth.
The recent uptake in venture capital funding has contributed to a rapidly growing start-up scene that may well give rise to the next

</td><td>
Industrial dynamics and business innovation

Korea's strong embeddedness in global value chains creates a high reliance on geopolitical and global economic stability. Due to its relatively low market size, it is particularly affected by rising trade tensions and protectionism tendencies, for instance, as a consequence of United States-China disputes in recent years.
Korea is missing future major opportunities due to its knowledge-intensive service sector lagging that of other major innovative economies.

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</table>

Korean innovation leaders, particularly in knowledge-intensive services industries, which are critical for the digital transformation.

- Cultural attitudes regarding risk taking and openness to foreigners, as well as creativity, are changing with the younger generation, who are more exposed to international ideas and practices, as well as the onset of more practical and innovative education curricula.
- Korea can leverage its lead status in Asia and globally to set standards and lay out strong infrastructures, particularly as China increasingly seeks to serve its large domestic market.

Research institutes and higher education

- Recently, the government has initiated several efforts to increase flexible funding for research and encourage universities' autonomy.
- Knowledge flows and technology transfer from universities and public research institutes to industry have increased in recent years. Leveraging linkages between research institutions and industry can foster interdisciplinary strategic partnerships and boost co-creation and, thus, disruptive innovation.
- Korea can promote technical skills development by expanding on past initiatives, such as vocational training and lifelong learning for the old-age workforce, addressing SMEs in particular.
- Korea can strengthen the ability and incentives for universities to do more high-impact research (excellence, breakthrough, relevance).
- Korea can foster interdisciplinary research by merging public research institutes according to disciplines, which would improve co-ordination and reduce fragmentation and inefficiencies.
- Korea can use research institutes as policy tools to tackle societal challenges in large and ambitious initiatives, leveraging knowledge, skills, technological infrastructure and industrial networks.

Governance and initiatives to tackle societal challenges

- Korea can leverage its leading position in certain green technologies, including batteries for electric cars, to meet the increasing global demand for green innovation.
- Korea has ambitious government strategies and initiatives (e.g. Net Zero Policy, Green New Deal) to raise awareness of researchers, civil servants, industry and civil society on the societal challenges imperative and alleviate fears of disruption to jobs and the economy.
- Korea is increasing its attention on mission-oriented innovation policies to address key national societal challenges in a better-oriented and co-ordinated way to structure collective action across silos.

- SMEs' high and persistent productivity gap with large companies despite considerable resources being provided to SMEs risks Korea's industrial base falling behind, particularly in ICT technology adoption.
- Failing to open up to foreign cultures could damage prospects for deeper global integration, including global scale-up of Korean start-ups and unicorns, better integration in the global science system and achieving global societal goals.

Research institutes and higher education

- The ongoing contraction in the higher education sector (due to a drop in the number of students) risks exacerbating social and regional inequality.
- A rising level of development and an increasing amount of fundamental scientific knowledge required to keep up with technological advancement creates a need for intensified industry and academia collaboration. The prevailing fragmentation of the public research institute system is not conducive to strengthened co-operation and co-creation.

Governance and initiatives to tackle societal challenges

- Widening societal gaps need to be addressed with proactive policies to ensure inclusive growth, e.g. population ageing will reduce Korea's labour force, which requires adequate and up-to-date skills for its STI system.
- Lack of actions in pursuing necessary change to address climate change, such as phasing out fossil fuels, due to concerns with regard to demographic and economic disruptions has led to a slow start in society for the green transition.
- The unabated barriers to collective action across sectoral, disciplinary and policy silos hinder Korea's ability to respond with the necessary scope and scale to rising societal challenges.

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Notes

1. As noted above, an additional future recommendation of overall STI governance will further reinforce this capability.

2. The pre-feasibility test is a review process that conditions the launch of large programmes.

3. Note by the Republic of Türkiye:

   The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Türkiye shall preserve its position concerning the "Cyprus issue".

   Note by all the European Union Member States of the OECD and the European Union:

   The Republic of Cyprus is recognised by all members of the United Nations with the exception of Türkiye. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

4. Calculated as the sum of the forward participation (domestic value added in foreign exports as a share of gross exports) and backward participation (foreign value-added share of gross exports) in GVCs.

5. Number will be updated when new MSTI statistics become available in April 2023.

6. This includes the share of “middle-market firms” and SMEs.

7. Compared to the United Kingdom (81%) and Germany (75%) in 2018. OECD calculations based on OECD Structural Analysis Database (STAN).

8. Korea is expected to have the sharpest increase in the ratio between 2021 and 2050. The old-age to working-age demographic ratio is defined as the number of individuals aged 65 and over per 100 people of working age defined as those aged 20-64.

9. Having slightly decreased from 2019, mostly due to COVID-19 disruptions in the economy, and notably the services sector, which largely employs women.

10. It is worth noting that Ireland is ahead of Korea, but this is due to a specific context of mostly US-based multinationals relocating manufacturing operations to better access the EU market.

11. Six target HCI sectors: 1) iron and steel; 2) non-ferrous metal; 3) machinery; 4) shipbuilding; 5) electrical appliances and electronics; 6) petrochemicals.

12. Artificial intelligence, 5G and 6G, quantum technology, space and aeronautics, rechargeable battery, cybersecurity, advanced biology, advanced robotics and manufacturing, semiconductors and display, and hydrogen.

13. In the 2021 InterNations Expat Insider ranking, Korea ranks 47th out of 59 destination countries surveyed globally, with expats appreciating the quality of life, in particular healthcare, safety and transportation, but reporting they have difficulties settling down, experience difficulty making local friends, struggle with learning the language and more generally do not feel at home. The HSBC Expat Explorer study shows similar results, pointing out barriers particularly linked to career progression, social relations and raising children in Korea.

14. The Green Future Index presents the comparative ranking of 76 nations and territories on their ability to develop a sustainable, low-carbon future. It measures the degree to which their economies are pivoting toward clean energy, industry, agriculture, and society through investment in renewables, innovation and green policy.

15. The other two pillars are “carbon emission” (Korea 42nd) and “climate policy” (23rd).

16. CO_2 intensity of GDP is calculated as kilograms of production-based CO_2 emissions per real GDP (kg/USD). Included are CO_2 emissions from the combustion of coal, oil, natural gas and other fuels.

17. In 2021, the government published the Roadmap for CCU Technology Innovation, which focuses on technologies for the conversion and utilisation of CO_2 that are needed and urgent for technology development. It aims to commercialise at least 14 CCU products by 2030 and includes 59 technologies that would require strategic investment to that end.

18. Basic metals, chemicals and chemical products, other non-metallic mineral products.

19. The initiative is led by the Climate Group (in partnership with CDP), which is a non-profit organisation working with businesses and national governments to address climate change. For more information, see https://www.there100.org/.

20. OECD calculation based on the OECD Patent Database (OECD, 2022[85]) and World Bank Population data (World Bank, 2022[86]).

21. Institutes of Science and Technology – a group of leading universities in S&T fields.

22. According to Woolcock (1998), social capital, a broad term encompassing the norms and networks facilitating collective action for mutual benefit, including, but not limited to, trust. It is one of the key drivers of economic development, alongside with physical and human capital (labour) (Woolcock, 1998[88]).

23. These include KAIST, GIST, DGIST and UNIST.

24. UNIST, KAIST and Pohang University of Science and Technology (POSTECH).

25. The percentage in top 10% is the top 10% most cited documents in a given subject category, year and publication type divided by the total number of documents in a given set of documents; 10% among the top 10% cited would mean performance at the same level as the world average.

26. Technology readiness levels (TRLs) is a scale measuring the maturity of technologies originally developed at the National Aeronautics and Space Administration (NASA) during the 1970s. It ranges from TRL=1, which denotes basic principles research, through intermediary steps denoting technology concept formulation, experimental proof of concept, assessment of feasibility, validation of integrated prototype in laboratory, testing the prototype in a user environment, pre-production and testing, low scale pilot production, manufacturing fully tested, validated and qualified, up to TRL=9, which denotes a fully operational and competitive product. See, for example, EARTO (2014[87]).

27. The discussion seems to have been complicated by the fact that while the GRIs were mostly RTOs, they also did some big science and performed some of the technical functions carried out in government labs.

28. The institutional (block) funding of GRIs is generally about 40%. This is similar to the European average, though there are considerable variations: KIST has 53.2%, KICT 33.6%, KITECH 30.9%, while ETRI has 14.5%, due mostly to the fact that it has grown considerably due to the success in securing competitive project funding.

29. The mission drift is evident from the spending breakdown: while experimental development accounted for 43.7% in 2006, it dropped to 26.7% in 2020; applied research progressed from 35.8% in 2006 to 40.9% in 2020; and basic research from 20.5% in 2006 to 34.9% in 2020. This is further differentiated across the GRIs, as some of them (KIST, KFE, KASI, KRIBB, KRISS, KIGAM) allocate more than 50%, and up to 80% of their funding to basic research, while others (KICT, KRRI, KFRI, WIKIM) allocate more than 50% on experimental development and can thus be considered as RTOs.

30. Academic-industry co-publications, as a share of total publications, declined between 2009 and 2019 from around 5.9% to 4.5%. In Germany, they rose from 5.8% to 6.7% in the same period.

31. The initiative is supported by a dedicated secretariat under NST. See http://tlomarketing.com/.

32. For more information, see https://www.etriholdings.com/.

33. Seventeen GRIs, including KIST and KRISS, are the shareholders. For more information, see http://kstholdings.co.kr/kor/main/.

2 Korea's economic performance and framework for innovation

This chapter sets out an overarching framework for Korea's National Innovation System. It starts by summarising Korea's past and current economic performance by way of international comparison. Next, it highlights Korea's innovation system's key strengths, given its preparedness for transitional challenges, including the digital transformation, its growth in labour and multifactor productivity and innovation inputs. Subsequently, it elaborates on Korea's industry structure and how it sets the conditions for innovation, particularly regarding knowledge-intensive activities. Pursuant to a discussion of Korea's current positioning in global value chains and the impact it has on technological sovereignty and potential for innovation, this chapter finally addresses Korea's particular vulnerabilities in the face of arising societal challenges, notably the green transition and population ageing, and how these may affect framework conditions for innovation.

There are many contextual factors which have enabled Korea's remarkable success in catching up with advanced economies. Shaping industries of the future is generally dependent on a strong macroeconomic framework, including, among others, a robust industry structure, high labour productivity and a skilled workforce, as well as large investments and influx of talent from abroad. Moreover, governments need to strategically provide the baseline conditions which promote innovative activities, such as when allocating financial resources to research and development. Mounting societal challenges and global transitions are increasingly shaping the contextual conditions for businesses, academia and civil society to proactively engage in innovation and carry substantial risks, which calls for strategic and decisive government action to minimise these risks whilst taking advantage of emerging opportunities early.

This chapter sets out an overarching framework for Korea's National Innovation System,[1] how it has contributed to economic development in the past and its prospects for promoting continued growth in the future. The sections provide a comprehensive overview of the National Innovation System, in particular in view of its preparedness for transitional challenges, notably the digital transformation. The first section summarises Korea's past and current economic performance by way of international comparison with other OECD countries in particular. Secondly, Korea's innovation system's key strengths, such as its growth in labour and multifactor productivity and innovation inputs, are highlighted. The subsequent and third section elaborates on Korea's industry structure and how it sets the conditions for innovation, particularly regarding knowledge-intensive activities. Pursuant to a discussion of Korea's current positioning in global value chains and the impact it has on technological autonomy and potential for innovation in its fourth section, this chapter finally addresses Korea's particular vulnerabilities in the face of arising societal challenges, notably the green transition and population ageing, and how these may affect framework conditions for innovation.

Based on a comprehensive analysis, the chapter derives the following conclusions.

- First, Korea's rapid economic growth has been driven by a developmental state in the past which prioritised export-led growth, in particular in the manufacturing and ICT-intensive sectors. Furthermore, innovation inputs such as human capital and research and development expenditure are some of the highest worldwide and have contributed to Korean success in innovation, which manifests itself in global leadership, in particular in some digital technologies.
- Secondly, the speed of Korean catch-up has, in part, led to imbalances in industry and society as a lot of growth occurred in specific sectors, population segments and regions. For instance, knowledge-intensive services and non-ICT industries have significant potential and universities and SMEs in rural areas often lag behind those in the metropolitan areas where most innovative activity accumulates. The government has recognised this and launched multiple efforts to counter partially widening gaps in industry and society.
- Thirdly, Korea shows very strong internationalisation when considering its production value chains, which tend to be highly embedded globally. In view of recent geopolitical tensions, more strategic collaboration with like-minded partners may be a worthwhile choice for Korean technological autonomy. Furthermore, despite high investments from abroad as well as immigration of foreign students, there is potential for further growth and diversification.
- Finally, compared to other advanced nations, Korea is particularly strongly affected by some of the global transitions, notably population ageing and the green transition, which will require structural reforms to its established manufacturing industries, in particular in terms of achieving emission targets. There is ample scope for policy to shape the Korean innovation success story for the decades to come when addressing societal challenges effectively.

2.1. Korea's economic performance has been impressive and leads the digital transformation

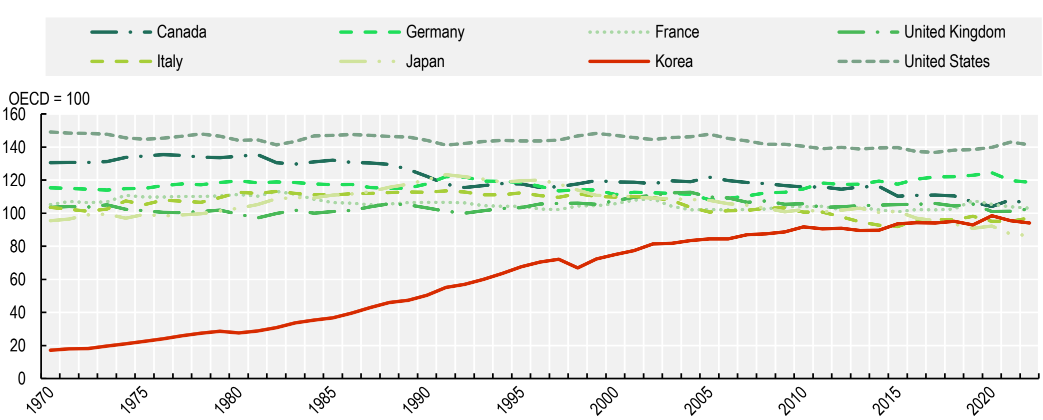
2.1.1. Korea has seen a highly successful transition to high-income status

Korea achieved remarkable success in catching up with other high-income economies between the early 1960s and the late 1990s. This has come to be known as the *Miracle on the Han River*, largely spurred by Korea's import substitution and export-oriented strategies in competitive manufacturing industries; high levels of investments in physical and human capital; improvements in institutional quality; and strong strategic initiatives spearheaded by the government and the private sector. Within its investment-led economic growth scheme, science and technology policies had been considered largely subordinate to industrial policies and a means to achieve rapid economic growth. Until the late 1970s and 1980s, the focus had been on technological capacity building for the heavy and chemical industries. However, as those industries started to decline, the government took on a more proactive role in fostering the development of core technologies, which would prove to be longer-term growth engines for the economy.

Korea's gross domestic product (GDP) per capita has caught up with that of high-income OECD economies and shown impressive growth since the 1970s when its income level relative to the OECD average stood at 17% compared to 99% in 2021 (Figure 2.1). In 2021, Korea had the 18th highest GDP per capita among OECD countries, with USD 48 985 per head. The compound annual growth rate (CAGR) of its GDP per capita had been as high as almost 12% during the 1980s but slowed to 7.2% in the 1990s and further declined to 4.8% in the 2000s. In the most recent decade, between 2011 and 2021, the CAGR has been 2.4%. Overall, the pace of growth has slowed and is converging with that of advanced OECD economies. In 2018, Korea's GDP per capita surpassed Japan's, one of its leading benchmarking countries.

Figure 2.1. GDP per capita for selected countries, 1970-2022

Current PPPs, OECD = 100



Source: OECD (2023), "National Accounts at a Glance", *OECD National Accounts Statistics* (database), https://doi.org/10.1787/data-00369-en (accessed on 19 June 2023).

Manufacturing contributes the largest share of Korea's GDP (27%), a share that has largely remained stable between 2011 and 2021 (Table 2.1). Services activities have grown in their contribution to GDP, notably in finance and insurance (5%), information and communication (3.6%), as well as in the sector of human health and social work (5.7%). It is worth noting that the growth trajectories of some of the sectors have been strongly affected by the coronavirus (COVID-19) pandemic as well as the ongoing war in Ukraine, which may see hindered imports of raw materials in the medium to long term, notably in semiconductor production, which is highly reliant on such inputs from Ukraine and the Russian Federation. This applies particularly to the cultural and other services sector, which saw modest growth between 2011 and 2019, with a CAGR of 1.4%. In contrast, the industry has significantly declined between 2019 and 2021 from KRW 46.5 billion (Korean won) to KRW 36.4 billion, reducing the CAGR over the past decade between 2011 and 2021 to -1.1%. Most sectors follow a similar trend. Nevertheless, some industries have not only grown between 2019 and 2021 but have also had a higher 2011-21 CAGR than 2011-19 CAGR, which implies even higher growth than before the pandemic. This holds notably for manufacturing, finance and insurance, as well as information and communications technology (ICT) industries and agriculture.

Table 2.1. Breakdown of real GDP by economic activity, Korea, 2011-21

Constant prices (2015)

Economic activity	2011		2019		2011-19	2021		2011-21
	KRW billions	%	KRW billions	%	CAGR	KRW billions	%	CAGR
Agriculture, forestry and fishing	30 571.2	2.07%	32 099.3	1.67%	0.54%	32 634.3	1.70%	0.60%
Mining and quarrying	2 345.5	0.16%	2 008.9	0.10%	-1.71%	1 879.5	0.10%	-1.99%
Manufacturing	40 2282	27.20%	485 401.2	25.22%	2.11%	517 025.0	26.99%	2.31%
Electricity, gas and water supply	39 822.6	2.69%	36 644.3	1.90%	-0.92%	48 610.4	2.54%	1.83%
Construction	72 504.5	4.90%	104 855.2	5.45%	4.18%	85 901.7	4.48%	1.55%
Wholesale and retail trade, accommodation and food services	143 211.0	9.68%	184 603.8	9.59%	2.86%	174 342.0	9.10%	1.80%
Transportation and storage	52 570.8	3.55%	60 688.7	3.15%	1.61%	55 309.9	2.89%	0.46%
Finance and insurance	70 355.9	4.76%	104 251.7	5.42%	4.47%	119 644.0	6.25%	4.95%
Real estate	113 402.0	7.67%	141 409.0	7.35%	2.48%	139 494.0	7.28%	1.90%
Information and communication	61 600.8	4.16%	83 040.6	4.31%	3.37%	91 317.4	4.77%	3.64%
Business activities	116 793.0	7.90%	175 384.5	9.11%	4.62%	162 133.0	8.46%	3.03%
Public administration, defense and social security	84 904.4	5.74%	121 818.0	6.33%	4.09%	115 623.0	6.04%	2.85%
Education	77 321.3	5.23%	94 401.2	4.91%	2.24%	89 488.1	4.67%	1.34%
Human health and social work	49 824.9	3.37%	89 510.8	4.65%	6.73%	91 405.7	4.77%	5.67%
Cultural and other services	41 211.8	2.79%	46 515.8	2.42%	1.35%	36 415.9	1.90%	-1.12%
Gross value added at basic prices	1 356 276	-	1 762 633.0	-	2.95%	1 759 054	-	2.39%
Taxes less subsidies on products	122 815	8.30%	161 865.1	8.41%	3.12%	156 837	8.19%	2.25%
Gross domestic product at market prices (GDP)	1 479 198	100.00%	1 924 498	100.00%	2.97%	1 915 778	100.00%	2.38%

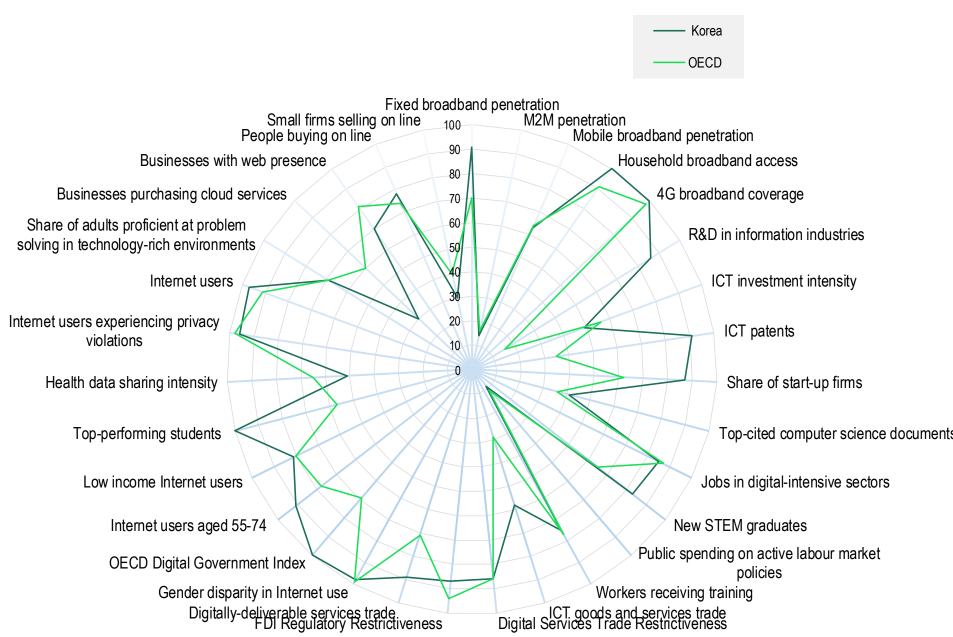
Note: CAGR: Compound annual growth rate. 2019 included to show the trend up until the COVID-19 pandemic.
Source: OECD calculations based on Bank of Korea Economic Statistics System (n.d.[1]), *National accounts*, https://ecos.bok.or.kr/#/SearchStat, June 2022.

2.1.2. Korea has demonstrated leadership in the digital transformation

Korea has demonstrated its global leadership in the digital transformation through its proactive stance in developing strategic initiatives, such as the national 5G vision, which was among the first among OECD countries. Korea was not only the first country worldwide to adopt 5G technology on a large scale in April 2019, but the government launched a comprehensive “5G+” strategy envisioning a whole infrastructure based on 5G technology for selected “core services and industries”, including smart manufacturing, smart cities, digital healthcare, information security, robots and drones. This initiative includes investments in the public sector and incentivising private investment, e.g. to encourage small- and medium-sized enterprises (SMEs) to uptake 5G technology. Furthermore, the government plans to ensure greater utilisation through cost reduction, and bridging divides in terms of access, to establish a domestic 5G industrial base as well as to support globalisation efforts for 5G technology by promoting 5G services internationally and by taking the lead in setting standards (Ministry of Science and ICT, 2019[2]). As of November 2021, 5G subscriptions exceeded 20 million, which is around 28% of mobile subscriptions (Ministry of Science and ICT, 2021[3]). This is higher than the regional average for Northeast Asia, which currently stands at 24%; North America at 20%; and Western Europe at 6% (Ericsson, 2021[4]).

The *OECD Going Digital Toolkit* shows that Korea’s positioning in the digital transformation is exceeding the OECD average on many indicators (Figure 2.2). Korea fares particularly well in the quality of students, the number of ICT patents, the Digital Government Index, the share of start-up firms among all businesses, research and development (R&D) in information industries, and broadband penetration. Regarding the latter, for instance, Korea has the highest share of fibre subscriptions among OECD countries, with about 86.6% of total fixed broadband in 2021 (OECD, 2021[5]). The advantages of fibre are multi-fold for businesses, including cost savings, improved reliability and security, as well as very high speed, allowing for the seamless transfer of increasing volumes and traffic of data, which in turn enables the adoption of productivity-enhancing digital technologies, such as cloud computing.

Figure 2.2. Korea’s performance on key digital transformation indicators, 2022



Note: Scores range from 0-100, with 100 representing the highest achievement by an OECD country. OECD score refers to the sample average for the OECD countries with available data. Top-performing students refers to proficiency in mathematics, science and reading. M2M penetration is the number of machine-to-machine SIM cards per 100 inhabitants. STEM stands for science, technology, engineering and mathematics.
Source: OECD (n.d.[6]), *Going Digital Toolkit*, oe.cd/4B7, July 2022.

Nevertheless, the share of businesses purchasing cloud services is low compared to the OECD average, reflecting the continuous struggles of SMEs, in particular, with digitalisation. This is notable because these firms feel burdened by the costs of switching to cloud services from traditional systems. The government is providing businesses with various support measures, including consulting, training, service development and vouchers, to boost the cloud industry. This being said, a lack of relevant skills is an underlying factor for the low uptake of new technologies, not least because SMEs employ a relatively large share of older workers who lag behind in terms of digital and ICT skills (Lee and Kwak, 2022[7]), as discussed later in this chapter. In this regard, it is of particular relevance that spending on active labour market policies is comparatively low, with 0.4% of GDP compared to an OECD average of 0.5%, far behind New Zealand (4%), Australia (1.6%) or Finland (0.7%). Considering Korea's strengths in ICT industries, increasing job readiness through incentives for employment and start-up creation, as well as training to ensure suitable employment, would benefit the digitalisation of SMEs.

The Government of Korea is also aiming to lead in artificial intelligence (AI). Besides its National Strategy for Artificial Intelligence (2019), it is working on a project that collects data (image, video, text, voice, etc.), processes it into a suitable form for AI modelling and presents it on AI Hub (aihub.or.kr) to revitalise and promote a wider AI ecosystem. Furthermore, the Ministry of Science and ICT has opted for a multi-stakeholder approach by encouraging strong involvement from private sector companies in different sectors, including automobile, telecommunications, semiconductors and gaming (World Bank, 2022[8]). Strong engagement by the government is indeed complemented by extraordinary investments from the private sector, including in 5G and AI, most notably by Samsung Electronics, which, in May 2022, pledged USD 356 billion of investments into, besides its core area of semiconductors and bioproducts, high-tech areas such as AI and 5G as well as 6G over the next five years, with the majority of it being foreseen for inside Korea. This investment is expected to create around 80 000 jobs in the country (CNN, 2022[9]).

2.1.3. Korea's labour productivity has grown but remains below the OECD average

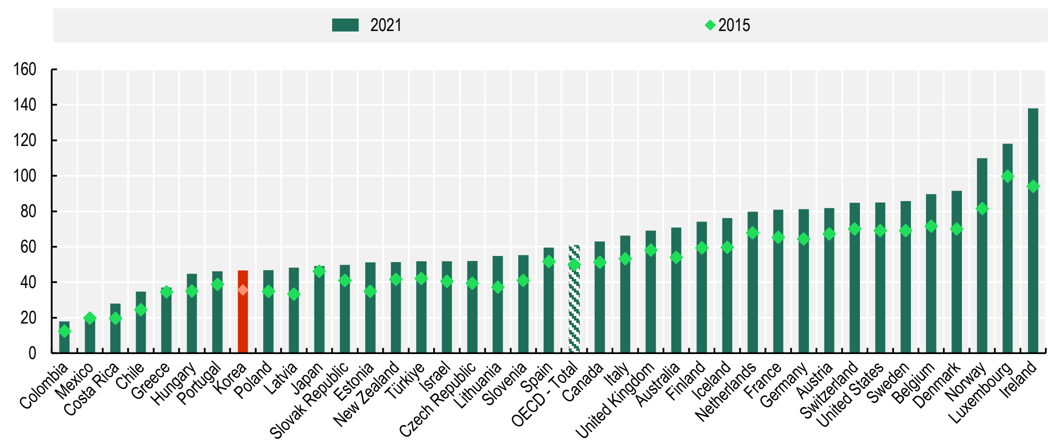
In Korea, the key growth challenge has shifted from accumulating physical and human capital to raising productivity through structural transformation (Swinston, 2021[10]). This calls for rethinking the past success factors that have led to Korea's rapid economic catch-up. Depending on whether Korea makes necessary adjustments and is open to experimentation, such challenges may remain risks or be translated into opportunities.

Labour productivity is the key dimension of a country's economic performance. In Korea, relatively high labour productivity growth until the last decade (7.4% in 1980-99 and 4% in 2001-12) helped reduce the productivity gap (OECD, 2016[11]; OECD, 2019[12]). Thanks to sustained productivity growth, wage growth has been among the strongest in OECD countries (OECD, 2021[13]). As a result, working conditions have significantly improved, and the share of workers working very long hours has been significantly reduced. The labour market has become relatively more inclusive as the share of low-income workers has decreased from 17% in 2006 to 13% in 2019 (compared to an OECD average of 11% in 2019), and the gender pay gap narrowed from 39.5% in 2010 to 32.5% in 2019 (OECD average: 12.5%) (OECD, 2021[14]). However, there exists further scope for progress as, despite continued growth, the productivity level remains below that of most advanced economies and the OECD average (Figure 2.3).

A major reason for low labour productivity in Korea is that the economy's skill composition does not, in part, adequately correspond to business needs, in particular in technology-intensive sectors. Korea's exceptionally high educational attainment (69.8% of 25-34 year-old adults with tertiary education compared to the OECD average of 45.6%) as a source for innovation is considered a role model for many countries. However, the limited availability of workers with the skills required for available jobs demonstrates that their skills are not well-utilised in the market (OECD, 2022[15]). For instance, according to the Survey of Adults Skills (a product of the Programme for the International Assessment of Adult Competencies, PIAAC) (Figure 2.4), the share of adults reaching the highest level in problem solving in technology-rich environments is relatively low, in particular in comparison with other innovation leaders, such as Finland, Japan and Germany. Furthermore, in 2018, Korea had the second-highest rate of adults failing the ICT test in the OECD Survey of Adult Skills, as further explained in Chapter 4.

Figure 2.3. Labour productivity in Korea and selected countries, 2015 and 2022

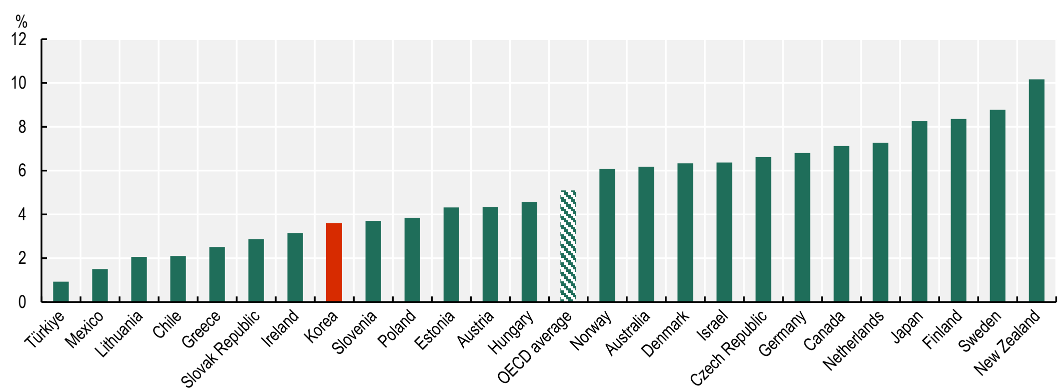
GDP per hour worked, USD, current prices, current PPPs



Note: Current prices (PPP). Data for 2022 or latest available.
Source: OECD (2023), *Productivity Statistics* (database), oe.cd/il/4B8 (accessed on 22 June 2023).

Figure 2.4. Adult proficiency in problem solving in technology-rich environments in Korea and selected countries, 2018

Percentage of adults with the highest level of proficiency in problem solving in technology-rich environments

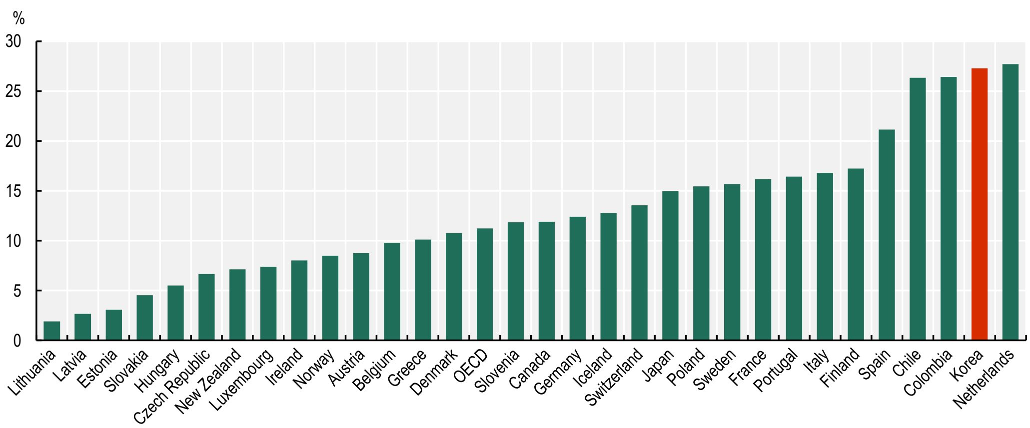


Note: Highest level refers to level 3 out of 3.
Source: OECD (2018[16]), *Survey of Adult Skills (PIAAC)*, oe.cd/4BE, June 2022.

Even though technology literacy and proficiency are improving dramatically among the younger generation, skills mismatch continues to be a concern due to student preferences to enrol in university programmes that do not necessarily correspond to their interests or skillsets – in order to study at top-ranked institutions (OECD, 2022[17]). In addition, the skills mismatch also relates to the high number of fixed-term contracts in Korea. The correlation between mismatch and contract types, i.e. whether workers on fixed-term contracts are more likely to be mismatched relative to indefinite contract holders, has proven to hold significance in Korea as well as Ireland, Poland and Sweden (Adalet McGowan and Andrews, 2015[18]) (OECD, 2022[15]). Furthermore, temporary employment has been shown to reduce technology efficiency and productivity in firms (Choi, Choe and Lee, 2021[19]), which is of particular relevance for Korea since it has the second-highest temporary employment rate among OECD countries (26%), second only to Colombia (27.3%) (OECD average: 11.4%) (Figure 2.5). This may be the consequence of the high protection of workers under fixed contracts. Korea has the 13th most stringent dismissal regulation for workers on regular contracts (index 2.41), next to Sweden (2.45), compared to the OECD average of (2.06) (OECD, 2020[20]).[2] In the end, both the youth and female workforces, for whom the incidence of temporary employment is disproportionately high, may face deteriorating working conditions (Swinston, 2021[10]), affecting economy-wide productivity by causing an inefficient "revolving door", whereby workers who are constantly subject to short-term employment and unemployment, see reduced investment in on-the-job training measures and thus less accumulation of skills (Cabrales, Dolado and Mora, 2014[21]).

Figure 2.5. Temporary employment rates in Korea and selected countries, 2022

Temporary employment % of dependent employment, 2022 or latest available year



Note: Temporary employment includes wage and salary workers whose job has a pre-determined termination date. National definitions broadly conform to this generic definition but may vary depending on national circumstances.
Source: *OECD Labour Market Statistics: Employment by permanency of the job: incidence* (database), oe.cd/dp/4Bq (accessed on 21 June 2023).

2.1.4. Korea's GDP growth has been supported by a high level of multifactor productivity

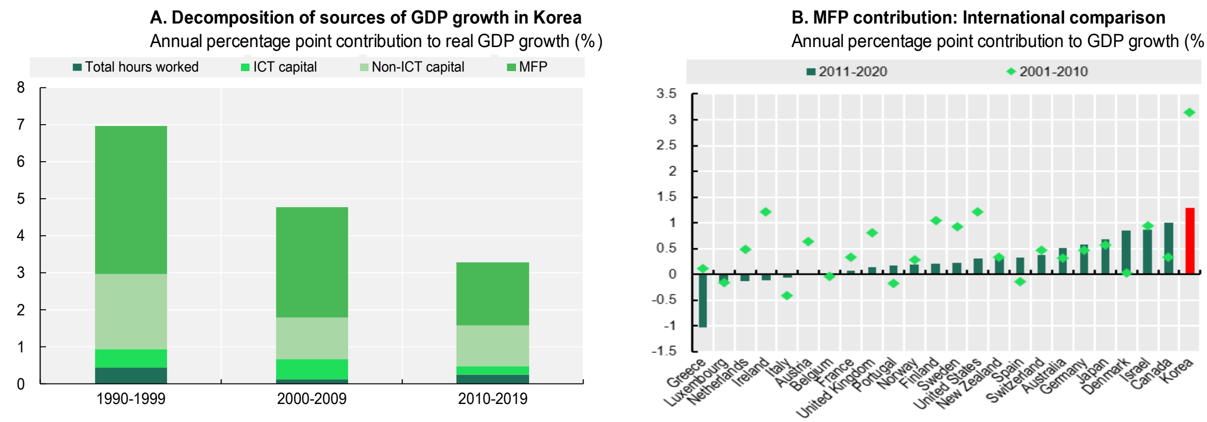
Among the various enablers of Korea's successful catch-up is its high multifactor productivity (MFP) growth. MFP represents the efficiency of the combined use of labour and capital in the production process (OECD, 2019[12]). Growth in MFP is measured as a residual, therefore capturing what cannot be explained by capital and labour inputs. Its variations reflect, for instance, the changes in management, organisational aspects, general knowledge and spillover from production factors and are generally associated with innovation and technology.

The relatively high contribution of MFP to GDP growth helps explain Korea's catch-up economic trajectory (Figure 2.6, Panel A). Capital services and MFP accounted for the biggest part of GDP growth in most OECD economies in the last two decades. However, the pace slowed over time, in parallel with the slowing pace of overall economic growth. Moreover, nearly all countries experienced a deceleration in MFP growth after the global financial crisis. Korea witnessed a significant slowdown along with Finland, Sweden, the United Kingdom and the United States (OECD, 2019[12]). Nevertheless, MFP's contribution to GDP growth in Korea remains the highest among OECD countries (Figure 2.6, Panel B).

When considering industry sectors, the trend in the manufacturing sector is concurrent with the overall change in MFP (Swinston, 2021[10]). Swinston finds that MFP growth in export-oriented manufacturing, especially in the high-tech industries, has been a key driver for Korea's economic growth. MFP in high-tech sectors soared from the 1980s until the 1990s, which coincides with the period when Korea's electronics industry greatly expanded. Helpful findings are presented by Foster-McGregor and Verspagen

(2017[22]), where MFP growth in Korea's manufacturing industry (78.6%) between 1995 and 2009 is found to have outpaced those of other countries except for the People's Republic of China (hereafter "China").

Figure 2.6. Multifactor productivity growth and GDP growth in Korea and selected countries



Source: OECD (2022[23]), *OECD Productivity Statistics* (database), oe.cd/il/4B8, May 2022.

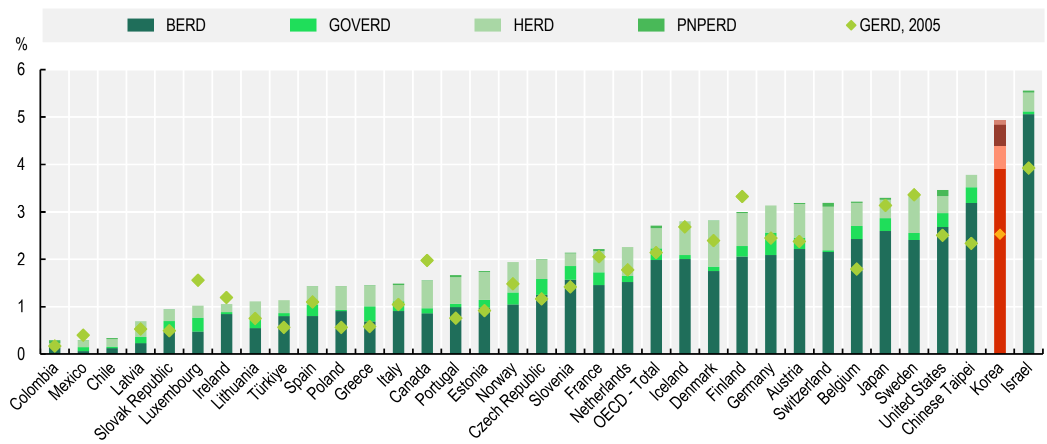
2.1.5. Korea is a leader in R&D spending

The extent to which countries mobilise financial and human resources for science, technology and innovation (STI) varies markedly across countries. Korea stands out among OECD countries for its high spending on innovation, as measured by gross expenditure on research and development (GERD) (Figure 2.7), amounting to 4.9% of GDP, which is second only to Israel. As is the case for most countries across the OECD, business expenditure on research and development (BERD) as a percentage of GDP (3.9%) significantly outweighs government (GOVERD) and higher education expenditure (HERD), which account for comparable shares with 0.5% each. In addition, overall GERD has increased significantly compared to 2005, when it stood at 2.5%, implying Korea not only belongs to innovation-intensive countries in terms of the highest absolute shares of GDP but also growth, with a CAGR of 4.1% since then.

In terms of human resources for innovation, Korea belongs to the OECD countries with the highest shares of R&D personnel per thousand labour force (Figure 2.8, Panel A). This share has demonstrated a steeper rise since 2005 compared to other innovation leaders and China. Notably, Korea has the highest share of R&D personnel in the business sector in absolute and relative terms (Figure 2.8, Panel B), with about 15 per thousand labour force. In most OECD countries, businesses account for the largest share of R&D human resources. This particularly holds for Korea, where comparatively small shares of personnel are in the higher education (2.8) and government (1.44) sectors. A more detailed breakdown of BERD and R&D personnel in businesses is provided in Chapter 3. HERD and GOVERD, as well as research personnel in the public sector, are discussed in Chapter 4.

Figure 2.7. Expenditure on R&D in Korea and selected countries, 2021

Percentage of GDP, 2021 or latest year available



Source: OECD (2022[24]), *Main Science and Technology Indicators* (database), oe.cd/msti, May 2023.

Table 2.2. Korea's expenditure on R&D by sector of performance and source of funds

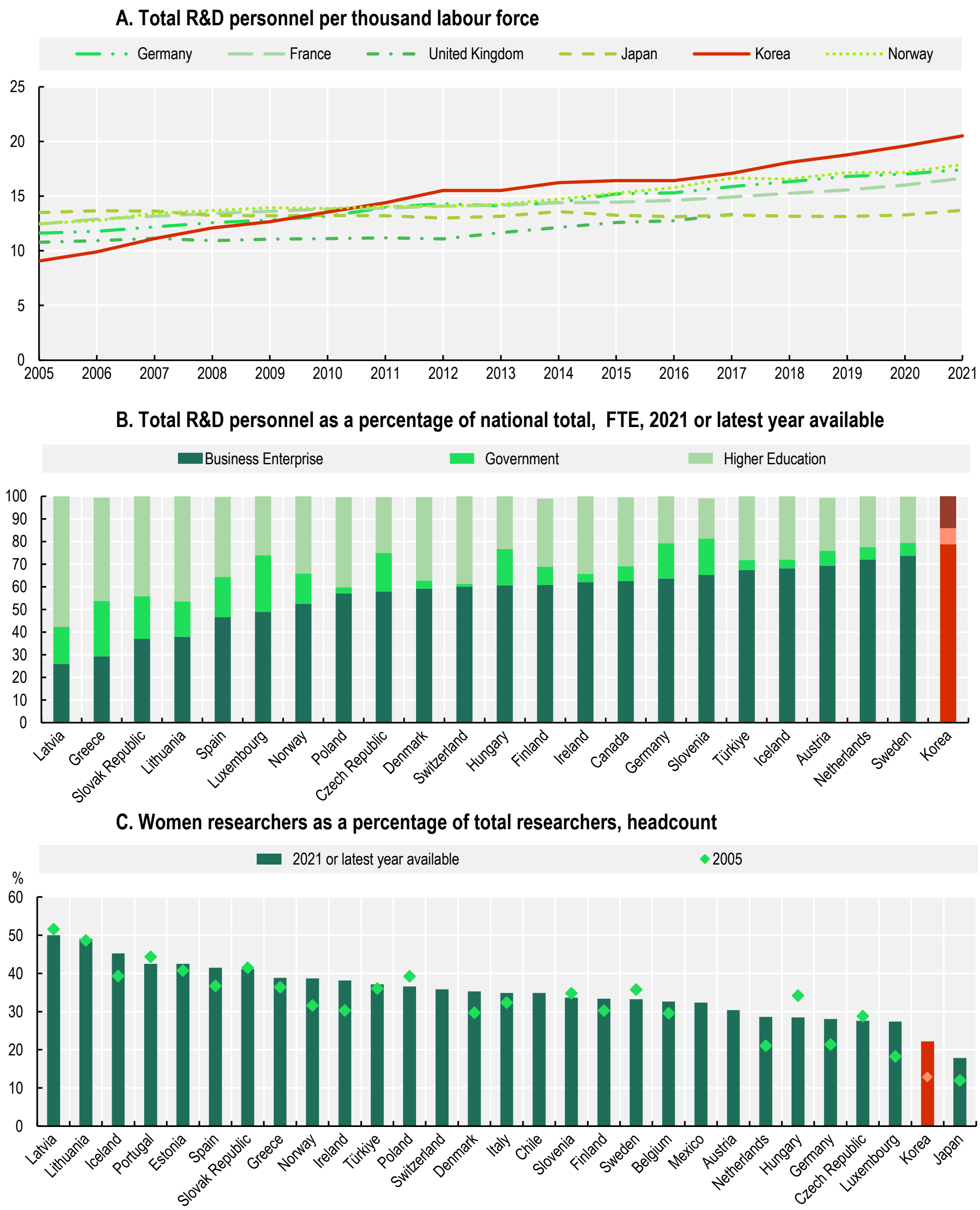
In USD, share of expenditure in parentheses

Sector of performance / Source of funds	Business enterprise	Government	Higher education	Total (performance)
Business enterprise	54 117.4 (97.8%)	202.3 (2.3%)	833.4 (12.3%)	55 153.1 (74.3%)
Government	2 952.3 (5.3%)	8 383.4 (96.2%)	5 345.3 (79.2%)	16 681.0 (22.5%)
Higher education	21.0 (0.03%)	16.3 (0.2%)	439.5 (6.5%)	476.8 (0.6%)
Private non-profit	16.1 (0.03%)	84.1 (1%)	76.5 (1.1%)	176.7 (0.3%)
Funds from abroad	430.4 (0.8%)	29.0 (0.3%)	55.2 (0.8%)	514.7 (0.7%)
Total (funding sector)	55 326.2 (100%)	8 715.1 (100%)	6 750.0 (100%)	74 217.7 (100%)

Source: OECD (2022[24]), *Main Science and Technology Indicators* (database), oe.cd/msti, May 2023.

Regarding the share of female R&D personnel in OECD countries (Figure 2.8, Panel C), Korea had the strongest increase from 2005, with 13% of human resources for R&D being female to 21% in 2020. Nevertheless, this rise occurred from relatively low levels, and as of 2020, Korea still only had the second-lowest share of female R&D personnel.

Figure 2.8. R&D personnel in Korea and selected countries, 2005-2021



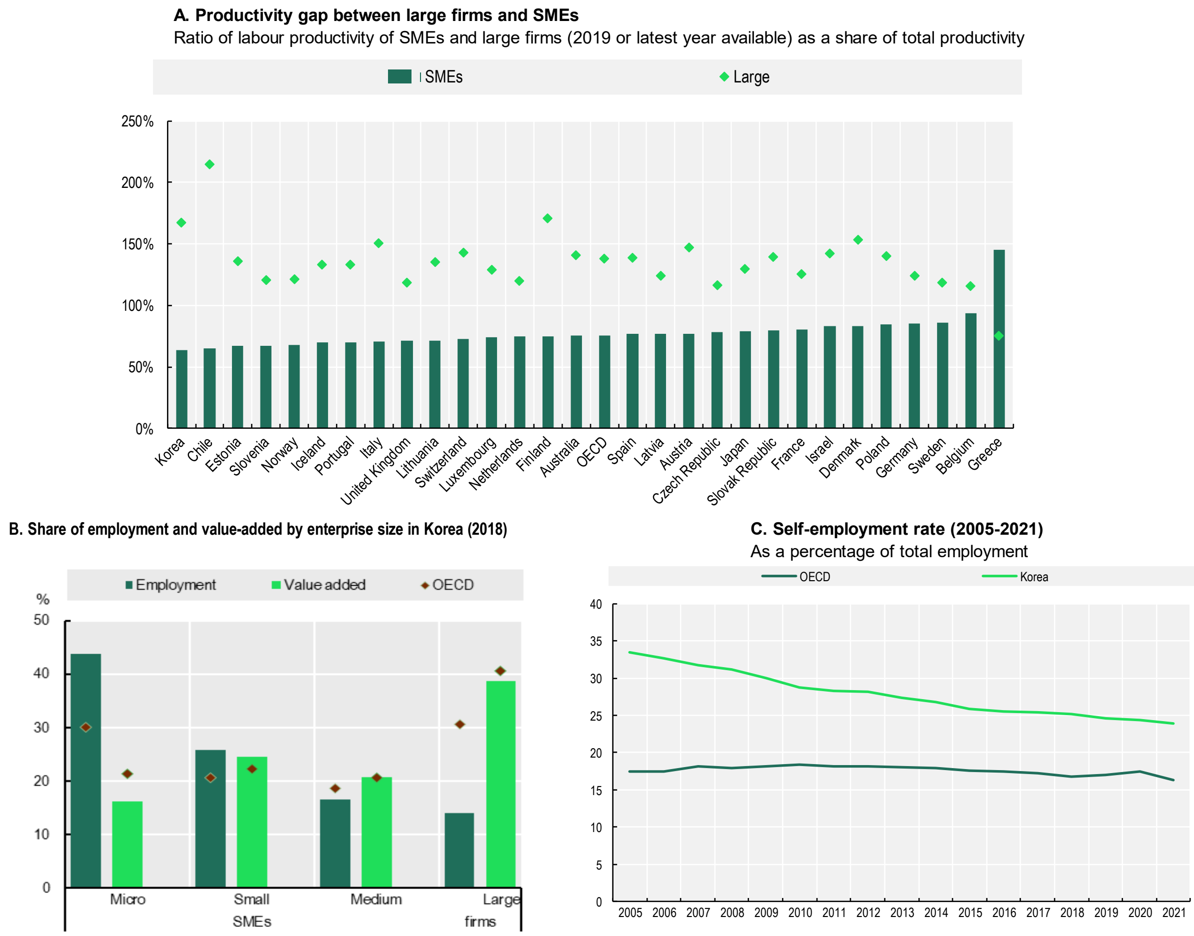
Note: In Panels A and B, R&D personnel is measured in full-time equivalents (FTE).
Source: OECD (2023), *Main Science and Technology Indicators* (database), oe.cd/msti, June 2023.

2.2. Korea's industry structure is largely imbalanced

2.2.1. Wide performance disparities exist between SMEs and large enterprises

Within the Korean economy, one striking observation is the dual productivity gap, first between SMEs and conglomerates and second, between manufacturing and services. Regarding the first, Korean SMEs are significantly less productive than OECD countries on average, while large firms tend to be more productive, implying one of the highest productivity gaps (Figure 2.9, Panel A). In many OECD countries, SMEs contribute most to net job creation, and strong SMEs tend to promote broad-based income gains across regions and industries. In this regard, innovative entrepreneurship is considered a means to achieving inclusive growth (OECD, 2017[25]). However, in Korea, the productivity of SMEs has been declining steadily since the Asian financial crisis in 1997, in marked contrast to the experience of large firms, which boosted their productivity growth, mainly through operational restructuring. Consequently, the government has ramped up its support to SMEs as a potential growth engine (Jones and Kim, 2014[26]).

Figure 2.9. Productivity gap between large firms and SMEs, share of employment and self-employment in Korea and selected countries, 2019



Note: In Panel A, large firms are defined as entities with 250+ employees and SMEs as those with 1-249 employees.
Source: OECD (2022[27]), *Structural Business Statistics (SDBS)* (database), oe.cd/4BI, May 2022; OECD (2021[28]), *SME and Entrepreneurship Outlook 2021*, https://doi.org/10.1787/97a5bbfe-en; OECD (2022[29]), *Self-employment rate*, oe.cd/dp/4BJ, May 2022.

Nonetheless, policies in Korea have sustained the survival of non-viable SMEs despite their dwindling productivity, therefore hampering economy-wide productivity growth (Jones and Lee, 2018[30]). Moreover, non-selective financial support to SMEs not only limits their chances to restructure the excess capacity but also encourages SMEs to remain small at the expense of efficiency gains, as noted in a previous OECD review (OECD, 2014[31]). Furthermore, exit rates of inefficient companies leaving the market were the third lowest in the OECD (OECD, 2017[25]), indicating in part a weakness in the insolvency regime, a longer time to discharge and the lack of an early warning system for bankruptcy. In addition, preferential treatment in public procurement has created unintended moral hazard, encouraging SMEs to overly depend on it at the expense of potential productivity gains. Finally, Korean SMEs receive exceptionally large shares of public funds spent on financial instruments, such as government loan guarantees that reached KRW 80 trillion in 2020 compared to KRW 40 trillion in 2007 (OECD, 2022[32]). Recently, however, the government, notably the Ministry of Economy and Finance, has incorporated policy aspects of enhancing competition and lowering support to less productive SMEs as part of the new government's economic policy directions (Ministry of Economy and Finance, 2022[33]).

A snapshot of the enterprise landscape in Korea supports such findings (Figure 2.9, Panel B). Employment of the Korean population is more concentrated in micro and small firms[3] (43.8% and 25.7%, respectively) than the OECD average (30.1% and 20.7%). In contrast, large firms account for only 13.9% of total employment compared to the OECD average of 30.6%. Self-employment in Korea is also exceptionally high, but generating lower value-added than the OECD average, although the gap is gradually narrowing (Figure 2.9, Panels B and C) (OECD, 2018[34]) (OECD, 2019[35]).

Uptake of digital technologies by SMEs

In many OECD economies, SMEs and start-ups play a central role in innovation as they tend to benefit from more freedom to experiment with new technologies. In particular, start-ups seek commercial opportunities often overlooked by existing firms (Jones and Lee, 2018[30]; OECD, 2010[36]). In this respect, digitalisation offers several advantages for SMEs to improve performance, spur innovation and enhance productivity to compete with larger firms on a more balanced level-playing field (OECD, 2021[37]). In addition, new ICT applications, such as big data analytics, cloud computing and the Internet of Things (IoT) combined, can enable novel production and organisational processes by increasing firm capacity for simulation, prototyping, decision making and automation (OECD, 2017[38]; OECD, 2021[37]). However, in many OECD economies, size-related gaps often act as a barrier to adopting digital technologies, and SMEs lag in the digital transformation.

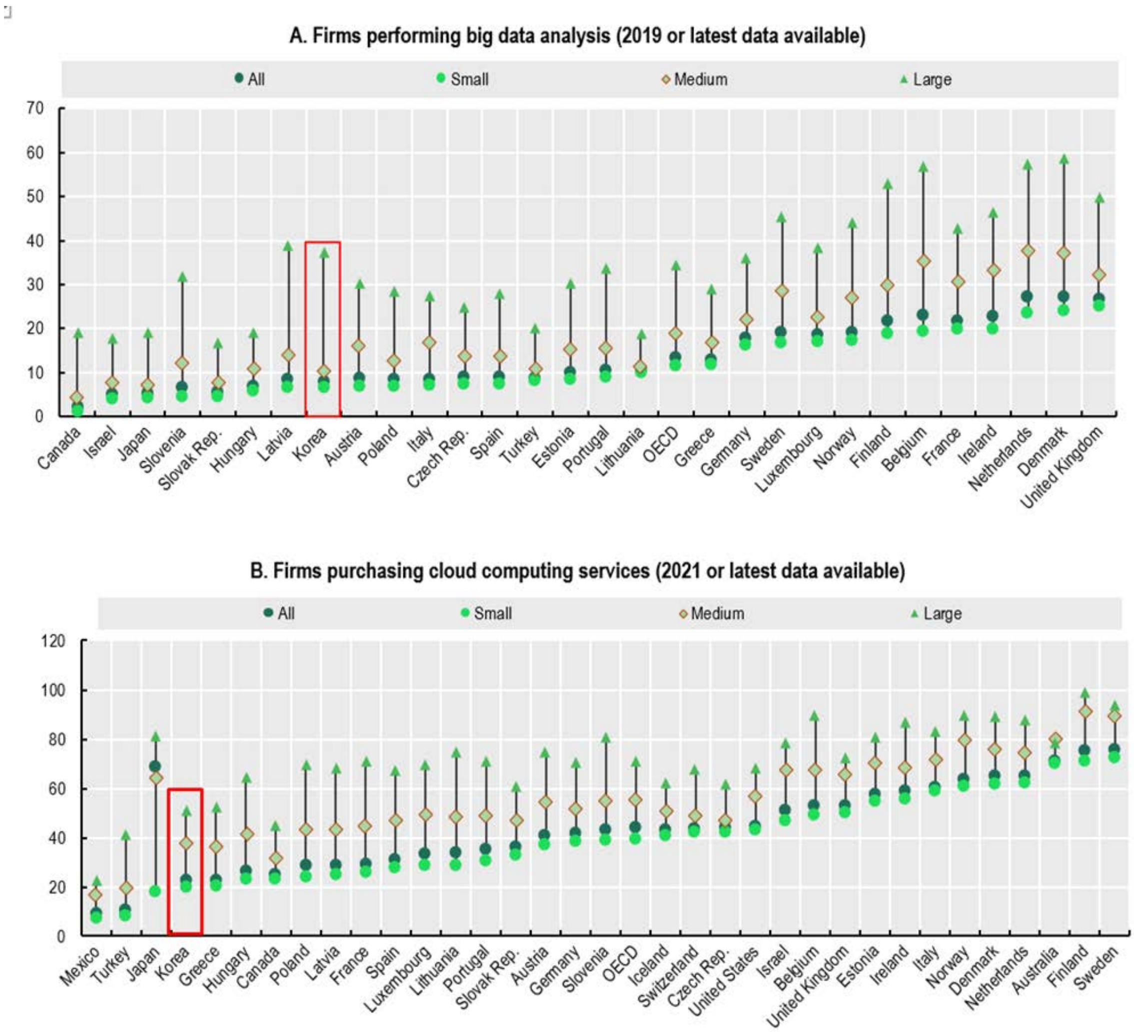
The progress of Korean SMEs, despite the country's leadership in ICT manufacturing and broadband deployment, is slower than that of other OECD economies (Figure 2.10).[4] As the figure illustrates, limited use of new technologies is a universal phenomenon (Panel B) across firms of all sizes, but SMEs face more significant challenges. This can partially be explained by the demographic composition of SMEs, where 43.1% of the workforce was over 50 in 2020 compared to 24.4% in larger firms (KOSTAT, 2020[39]). This has been a long-term trend in Korea, in part due to the low appeal of SMEs for younger skilled workers, while adult employees of SMEs tend to work out of necessity (OECD, 2020[40]). In turn, having lower-skilled employees may result in less labour productivity and revenues, which can further reduce employee remuneration, thereby creating a vicious cycle of lower wages and less appeal for skilled (young) workers.

Innovative firms

Innovative firms are those engaging in at least one product and process innovation (OECD, 2022[41]). The 2018 edition of the *Oslo Manual* defines two types of innovation: "product innovation" and "business process innovation".[5] The two types are often complementary, but business process innovation tends to be more widespread.

Figure 2.10. Share of firms using digital technologies in Korea and selected countries, 2019 and 2021

Percentage of firms in each employment size class



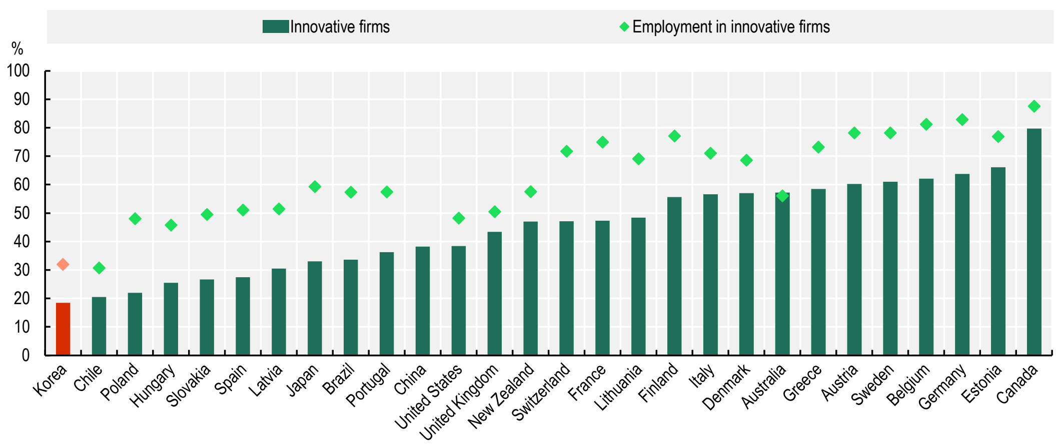
Note: Cloud computing refers to ICT services used over the Internet as a set of computing resources to access software, computing power, storage capacity and so on. Data refer to manufacturing and non-financial market services enterprises with ten or more persons employed unless otherwise stated. Size classes are defined as: small (10~49 persons employed), medium (50~249) and large (250 and more). The OECD average in both Panel A and B is a simple average of the available countries.

Source: OECD (2022[42]), *ICT Access and Usage by Businesses* (database), oe.cd/ds/54K, June 2022.

Among the OECD economies, Korea ranks lowest in terms of both the number of innovative firms and employment in innovative firms (Figure 2.11). The result is striking, considering Korea's second-highest R&D intensity among OECD countries and its notable performance in industries with high business process and product innovation intensity, such as manufacturing computer, electronic and optical products. However, a high proportion of reported innovation did not depend on R&D performance but on investments in intangibles. The relative dominance of SMEs in absolute number, although not unique to Korea, paired with their low uptake of digital technologies, helps explain the small share of innovative firms. Nevertheless, it should be noted that the start-up scene has gained significant dynamic in recent years. Since 2018, the number of unicorns has continuously increased, reaching 23 in the first half of 2022, which is an additional 5 compared to the previous year, despite more unfavourable economic conditions, such as the rise of global interest rates (Ministry of SMEs and Startups, 2022[43]). In addition, employment in start-ups grew by 9.7% between June 2021 and 2022, a three times larger increase than the overall employment increase of enterprises (3.3), suggesting that start-ups are emerging as an increasingly significant contributor to job creation in Korea (Lee, 2022[44]).

Figure 2.11. Number of innovative firms and employment in innovative firms in Korea and selected countries, 2016-18

As a percentage of total firms and total employment, respectively



Note: Innovative firms are those reporting one or more innovations in the reference period (2016-18).
Source: OECD (2022[45]), *Business Innovation Statistics and Indicators*, oe.cd/54O, April 2022.

In Korea, SMEs represent a key element of the social safety net (Jones and Lee, 2018[30]). Employees who plan early retirement from firms use their retirement allowances to create small firms, which explains the government's longstanding support for the SME sector. However, the current landscape poses mounting challenges to Korea's future growth since the dual job market may exacerbate social inequalities across enterprises of different sizes and their employees. As SMEs face significant shortages in skilled human resources, the problem is expected to worsen without targeted and interconnected sets of policy measures. Moreover, conglomerates tend to reap the benefits of the highly dualised labour market, which means they can attract the best-skilled employees while SMEs cannot compete.

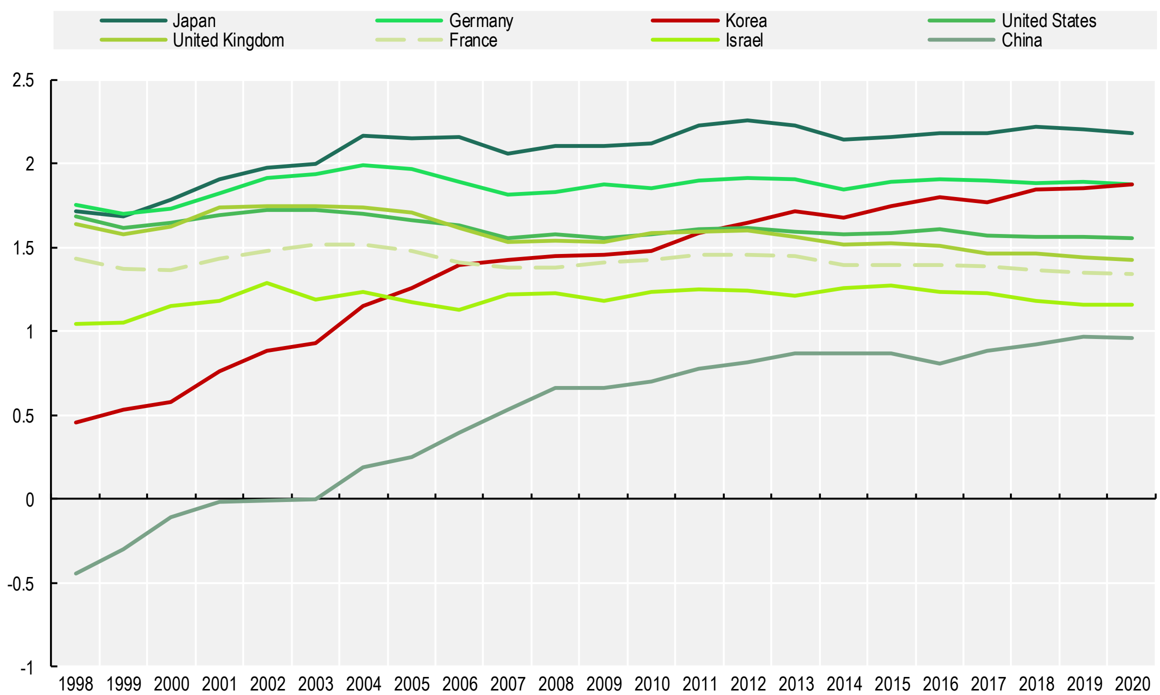
Furthermore, SMEs hold very limited leverage when negotiating cost sharing with large firms, as any gains in innovative activities are transferred to the chaebols. This occurs through several mechanisms that harm the level-playing field, including unfair price fixing, wage differentials and better access to technology. Many SMEs are integrated into the production processes of the chaebols in the manufacturing sector and, as such, must disclose their cost structure and, by extension, their potential productivity gains. This depletion of profit margins, in turn, impedes any possibility of raising wages and attracting better-skilled employees and investments in innovative activities.

2.2.2. Korea's industry structure is highly complex and strongly anchored in manufacturing

Korean industry has undergone a transformative shift towards high knowledge intensity, as measured by the Economic Complexity Index (ECI) (Figure 2.12). It ranked fifth in 2020 after Japan, Switzerland, Chinese Taipei and Germany. Its remarkable trajectory over recent decades from rank 32 in 2000 could only be mirrored by China, albeit at significantly lower levels, from 54th in 2000 to 28th in 2020. The ECI measures the degree to which complex products correspond to a country's productive capabilities. Higher complexity in industry structure is often perceived as indicative of stronger long-term economic growth

(Hidalgo and Hausmann, 2009[46]), lower income inequality (Hartmann et al., 2017[47]) as well as fewer greenhouse gas emissions (Neagu, 2019[48]). A high index implies that a given country's products are complex and indicates a larger number of interconnections between complex products, meaning that these can rely on shared capabilities (Alcorta et al., 2021[49]).

Figure 2.12. Economic Complexity Index for Korea and selected countries, 1998-2019



Note: Economic complexity provides an indication of an economy's capacity for future growth by calculating the relatedness (product space) between industries in a given location and, thus, the extent to which similar industries can benefit from comparable factor inputs.
Source: Observatory of Economic Complexity (n.d.[50]), *Economic Complexity Rankings*, https://oec.world/, May 2022.

Korea's high economic complexity is manifested in its relative strength and specialisation in highly advanced manufacturing industries, which accounted for 27% of real GDP in 2021, the second-highest share among OECD countries, while the services sector generated 56%. In comparison with Group of Seven (G7) economies, manufacturing has contributed a considerably higher share of value-added with 29.1%, even compared to Germany (22.7%), which is generally considered a manufacturing powerhouse (Figure 2.13, Panel B). In terms of labour productivity in manufacturing, Korea is also above the OECD average (Figure 2.13, Panel C).

The highest share of both GDP and value-added of the manufacturing sector comes from the complex ICT industries, generating 8.5% of GDP, followed by chemicals (4.2%) and electrical equipment (1.7%) (Figure 2.13, Panel A). These constitute a resilient and fast-growing sector of the Korean economy whose high value-added has remained constant since the global economic crisis in 2007 (OECD, 2017[51]).

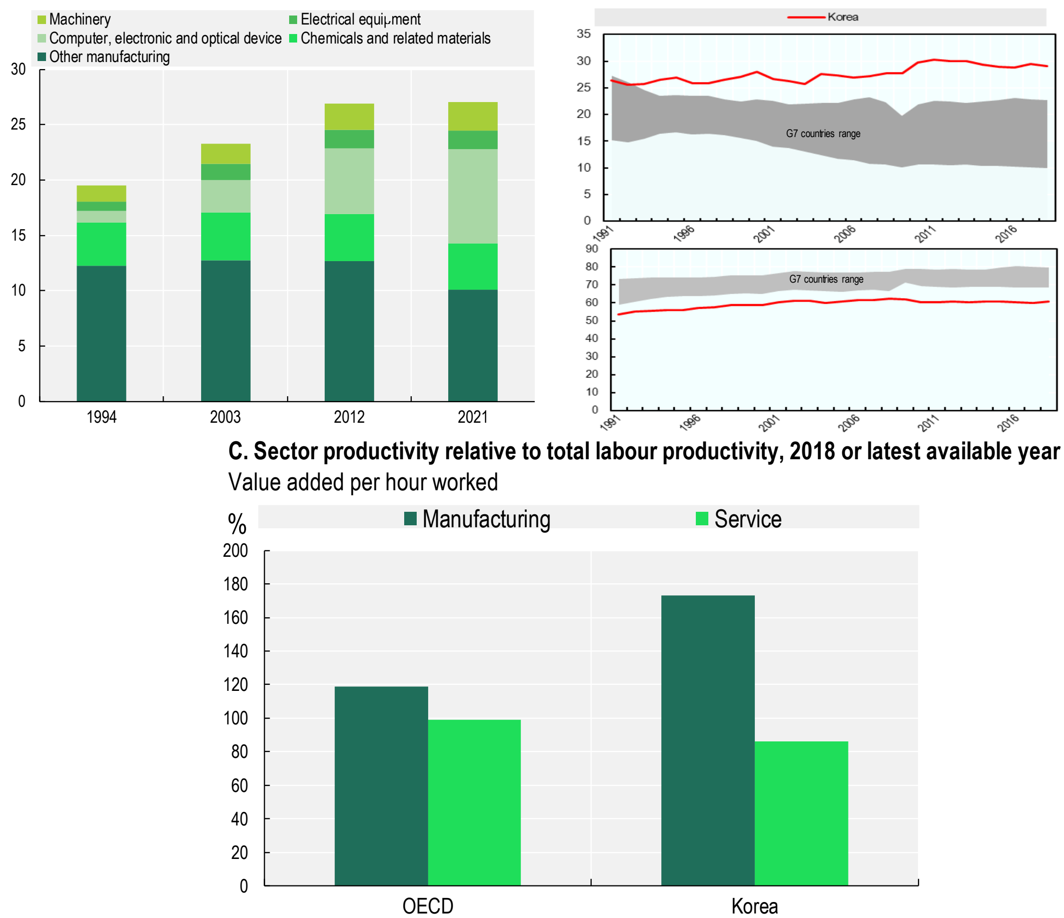
On the other hand, the service sector's relative underperformance has been lowering the overall productivity of the Korean economy, although it should be noted that some services may be embedded within manufacturing. The service sector's share of value-added has been below the G7 countries' range for three decades (Figure 2.13, Panel B) and its productivity below the OECD average (Figure 2.13, Panel C). By the same token, a comparison with the ICT industry in Ireland, for instance, shows how ICT services could be expanded to a much higher level than today. Both countries generate large value-added shares from their ICT industries (Korea first, and Ireland third, in the OECD), whereas in Korea, 31.4% came from ICT services; the share for Ireland was 66.4%.

Figure 2.13. Performance of Korea's manufacturing and service industries

A. Breakdown of manufacturing GDP by economic activities
As a share of GDP

B. Value-added share of manufacturing (top) /service industries (bottom)
In total economy, comparison with G7 countries

C. Sector productivity relative to total labour productivity, 2018 or latest available year (%)
Value added per hour worked

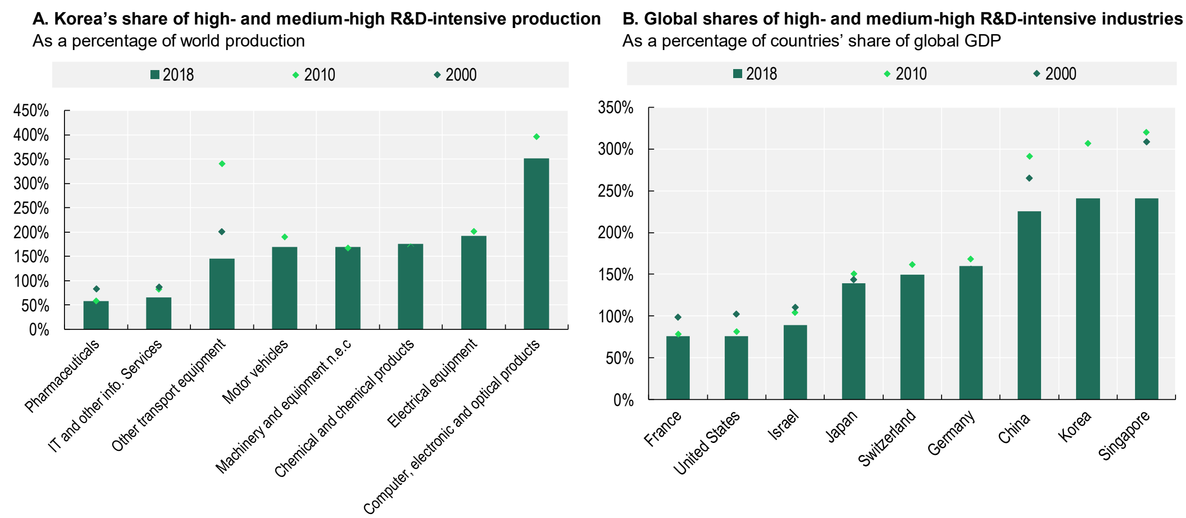


Note: Panel B: Reference years are 2018 for France, Germany, Italy, Japan, Korea, United Kingdom and the United States; 2017 for Canada. Panel C: Average of 32 OECD countries calculated for manufacturing and 34 for services. Per hour worked – total engaged. Calculation is value-added (current prices) per hour worked (- total engaged) for total manufacturing/services over total economy. Productivity of business sector services excluding real estate is 74% for Korea.
Source: Panel A: OECD calculations based on information from the Korean Statistical Information Service, https://kosis.kr/eng/. Panel B and C: OECD (2022[55]), *Structural Analysis (STAN)* (database), oe.cd/ds/4Bj, June 2023.

Furthermore, relative to the global share of advanced output in medium-high and high-technology-intensive sectors, Korean industry is strongly concentrated in the manufacturing-intensive sectors of computer electronic and optical products, electrical equipment and chemical products, showing a strong comparative specialisation (Figure 2.14, Panel A). In 2010, the relative specialisation to the global market reached a high of close to 400% in 2010 and has since subsided. In terms of international comparison, the cumulative share of all technology-intensive industries is above those of other innovation leaders and on par with China and Singapore, which further underscores the high degree of industry specialisation in advanced knowledge-intensive products (Figure 2.14, Panel B). Korea's strong specialisation indicates its strong leadership in these industries, although this does not come without risks. For example, with regard to smartphones, Samsung held its highest global market share in five years in April 2022, with around 24%

of smartphones sold (Canalys, 2022[52]). Similarly, Samsung was the market leader in semiconductors in 2021, with a share of 12.3% (Gartner, 2022[53]). This closely resembles Nokia's past success in Finland, which once was the dominant market leader for cell phones before failing to compete with new market entrants, notably Apple. Nokia's decline left the Finnish economy with a dramatic impact, causing one-third of Finland's drop in GDP and one-fifth of its loss in employment between 2008 and 2014 (OECD, 2017[54]).

Figure 2.14. Share of high- and medium-high R&D-intensive production in Korea and selected countries, 2000, 2010 and 2018



Note: ISIC 4.0 Revision definitions of high- and medium-high R&D intensity. World production refers to the world region as used in the OECD TiVA Database. N.e.c. – not elsewhere classified.
Source: OECD (2023[55]), "Trade in value added", *OECD Statistics on Trade in Value Added* (database), https://doi.org/10.1787/data-00648-en, May 2022.

In contrast to manufacturing, the share of technology-intensive services is below expected, based on Korea's weight in the global economy, and has shown a downward trend since 2000. Therefore, mainly due to its strengths in manufacturing, Korea shows strong aggregate output of advanced industries when compared internationally – being on par with China and Singapore – with the latter's performance significantly driven by a strong specialisation in high-value-added services.

2.2.3. Service sector growth can help realise Korea's untapped innovation potential

The reasons for Korea's relatively weak performance in the service sector are multi-fold. Historically, Korea's traditional export-led growth model siphoned capital, human and other resources away from services and towards manufacturing, resulting in relatively lower capital intensity in the former (OECD, 2016[11]). Park and Shin argue that while employment in the services sector has grown exceptionally fast, labour reallocation from manufacturing to services did little to contribute to productivity growth (Park and Shin, 2012[56]). In other words, according to Eichengreen, Perkins and Shin, this has created the "within effect" where the economy experienced productivity increases, but the sectoral shares remained constant (Eichengreen, Perkins and Shin, 2012[57]). Low productivity of senior employees in micro-enterprises in services sectors has become a common phenomenon in Korean industry and is a direct effect of rapid deindustrialisation.

Government regulations and restrictions to service sector growth

Insufficient competition has prevented the services sector from advancing in terms of growth and productivity (Jones, 2009[58]). In terms of industry structure, as Korea became more integrated into the global economy, conglomerates that are dominant in the manufacturing industry have shown a tendency to perform services in-house rather than contracting them out. In addition, relatively high levels of regulation also weigh on the service sector's growth and hinder newcomers' entry into the market. Competition encourages existing companies to become more innovative and increase investment, thereby contributing to economy-wide productivity growth. However, according to the product market regulation (PMR) index, which covers both manufacturing and services sectors, Korea is one of the least competition-friendly countries in the OECD (sixth-most stringent at 1.7)[6] compared to the OECD average (1.4) (OECD, 2018[59]) (Figure 2.15, Panel A). Korea is more restrictive than the OECD average for four sub-indices, particularly regarding barriers to market entry in service and network sectors[7] (Figure 2.15, Panel B), where Korea imposes more stringent regulations than other OECD countries in almost all sectors except for air and water transport.

Regulations in all six categories of professional services and retail distribution are stricter than the OECD average, with higher entry requirements and distortive business conduct regulations. However, since 2019, in an attempt to allow new firms to enter the services sector without being subject to prevalent legal requirements, the government has launched regulatory sandboxes in ICT convergence, industrial convergence, financial innovation, regulation-free special zones, special R&D zones and "smart city" (Office for Government Policy Coordination, 2022[60]).

Business enterprise R&D in services

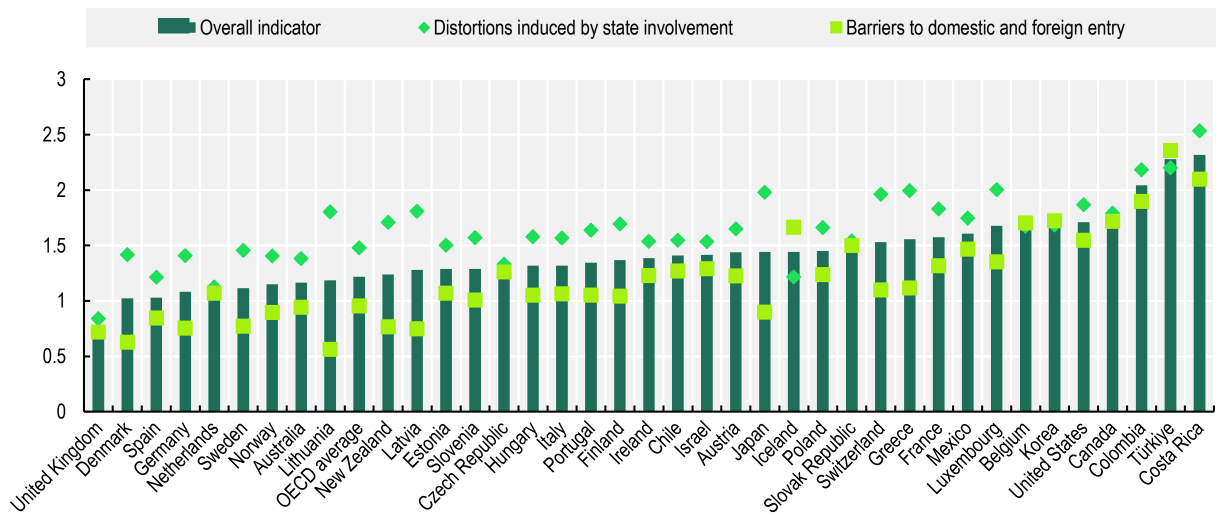
Low levels of BERD in services have been noted as another limiting factor for the sector's growth. BERD in services is at 0.4% of total GDP, far below the best-performing countries of Israel and Sweden (Figure 2.16). It is worth noting that similarly manufacturing-intensive Germany has an even lower share of 0.3%. Limited investment in services R&D can stifle innovation and hinder expansion into high-value-added services, which holds particular importance as Korea's manufacturing sector matures and increasingly faces competition with developing economies (Park and Noland, 2013[61]).

Since 2010, the Korean government has prepared and implemented policy measures to boost firms' service R&D investments. Starting from the first Service R&D Promotion Plan,[8] national investment strategies, such as the Service Economy Development Strategy (2016),[9] the Mid- to Long-term Promotion Strategy, the Promotion Plan on Service R&D (2017),[10] and the Service Industry Innovation Strategy (2019)[11] include specific measures aimed at boosting BERD in services. In 2017, the government increased the R&D tax credits for firms by expanding the scope of private companies authorised to establish corporate R&D centres from 19 industries to all and by including novel technologies with growth potential as possible recipients. As a result, the share of services sector firms with R&D centres out of total service firms increased from 26.2% in 2011 to 34.1% in 2019, and the share of those with in-house R&D departments more than doubled from 11.8% to 26.8% during the same period (KITA, 2020[63]). Also, the Ministry of SMEs and Startups selected the Korea-Engineering Service Provider (K-ESP) in six designated industry fields to match with SMEs for R&D projects (KOSI, 2018[64]). Despite such positive developments, however, the impact of government policies has not yet fully materialised, leaving considerable room for improvement.

Figure 2.15. Stringency in product market regulation: Korea and selected countries, 2018

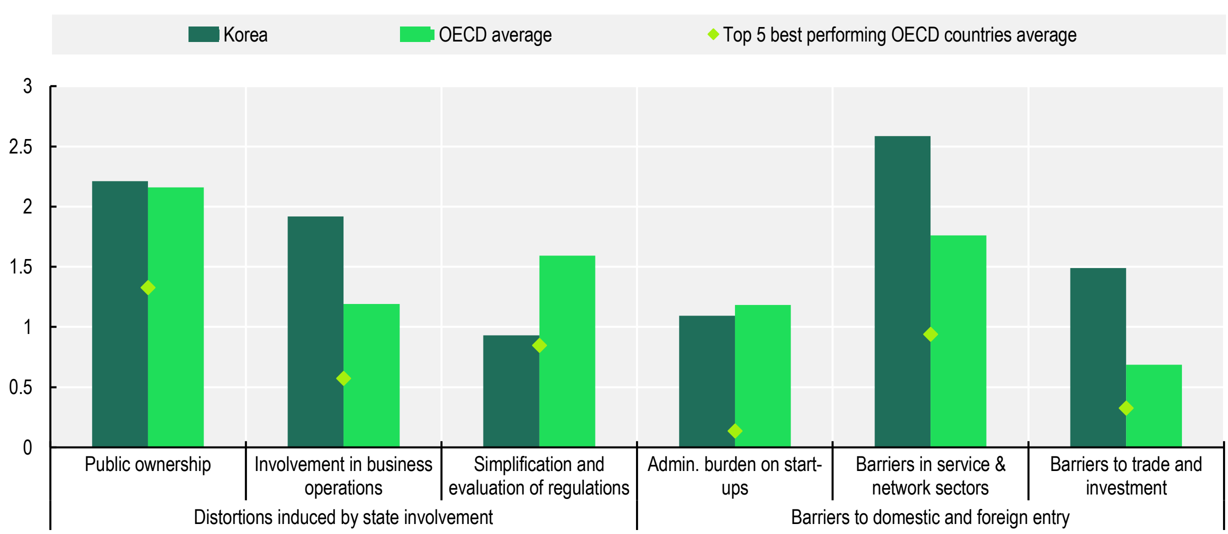
A. Economy-wide values of product market regulation and two high-level indicators, 2018

Scale of 0 to 6 from least stringent to most stringent



B. Korea compared with the OECD average and top five best performers on six medium-level indicators, 2018

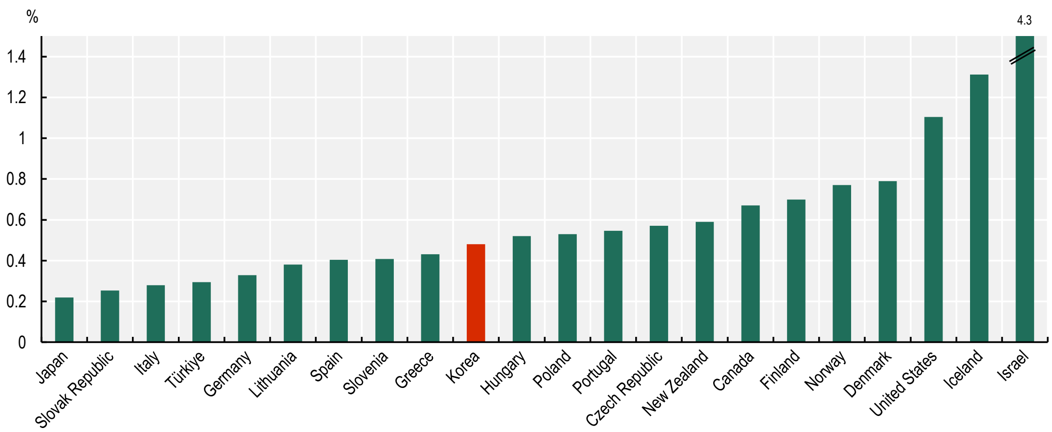
Scale of 0 to 6 from least stringent to most stringent



Source: OECD (2022[62]), *Indicators of Product Market Regulation*, oe.cd/54P, May 2022.

Figure 2.16. BERD in services, Korea and selected countries, 2020 or latest year available

As a percentage of GDP

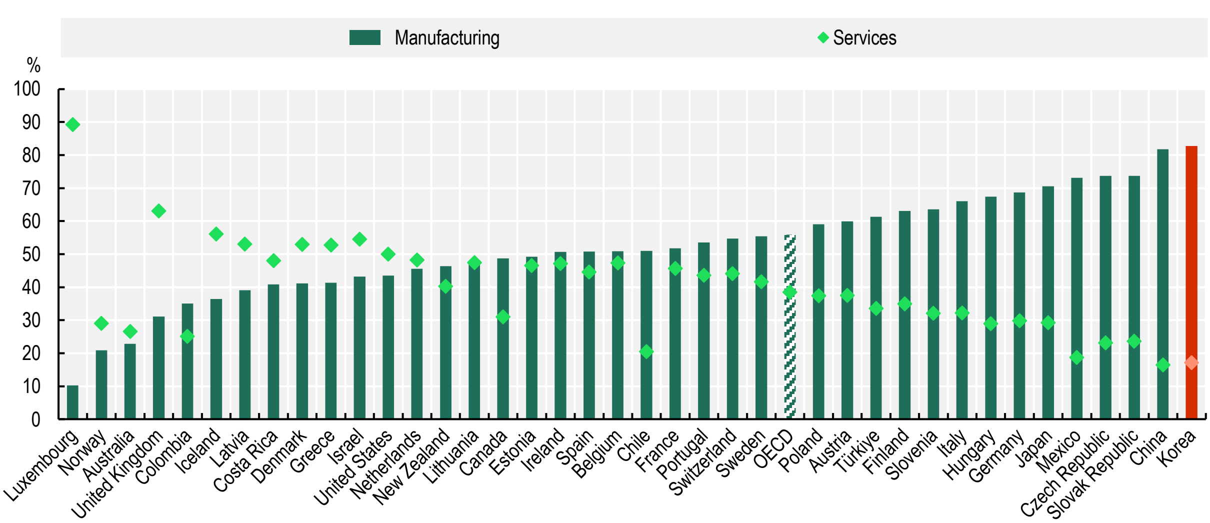


Note: Data correspond to 2021 for Korea
Source: OECD calculations based on OECD, ANBERD Database, http://oe.cd/anberd

2.2.4. Export-led growth continues to be driven by high-tech products with large room for expansion into knowledge-intensive services

The stark concentration of the Korean economy in manufacturing is apparent in its trade flows, with manufacturing accounting for 83% of exports, in contrast to only 16.4% for services, the strongest gap among OECD countries and higher than many other countries in Asia (Figure 2.17).

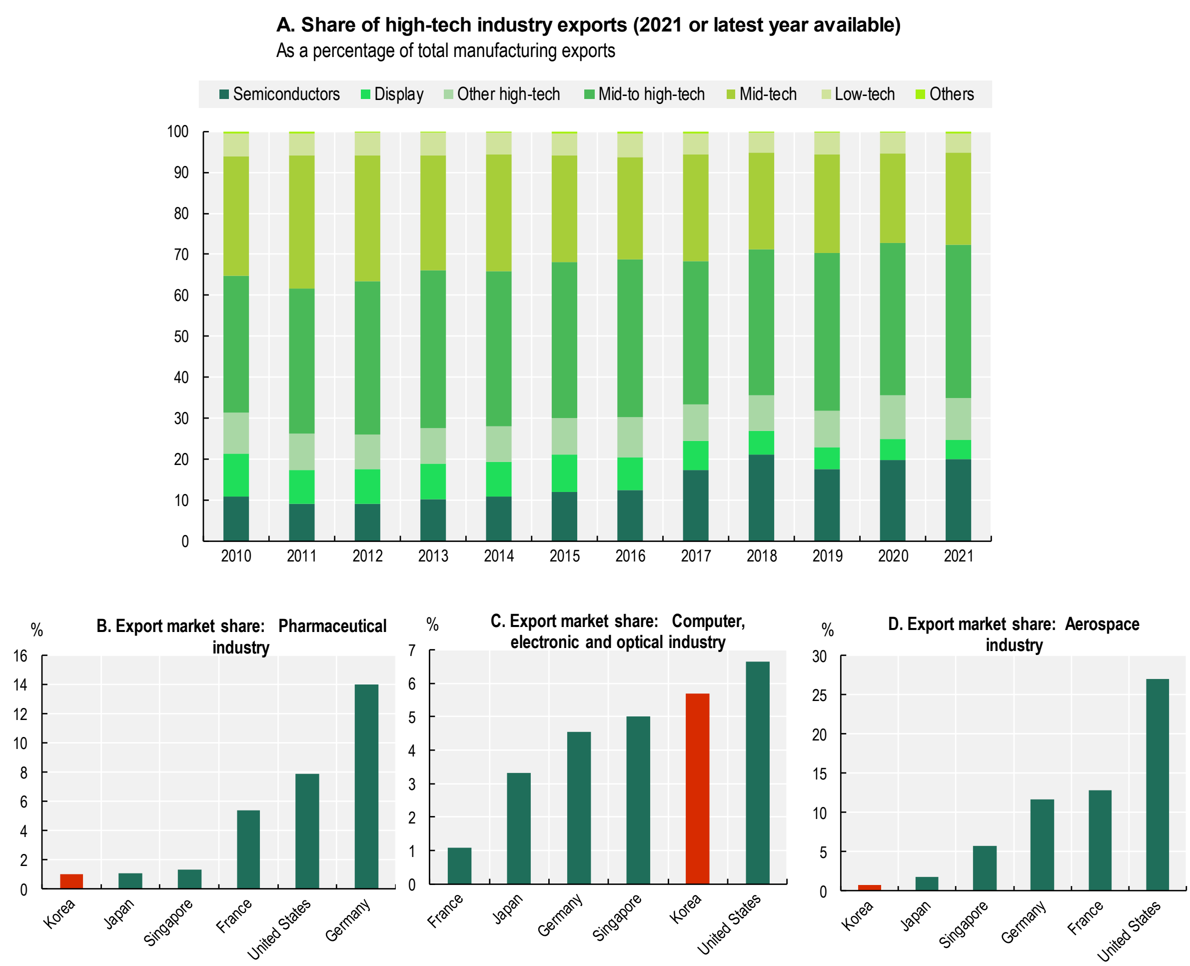
Figure 2.17. Share of manufacturing and services of gross exports in Korea and selected countries, 2018



Source: OECD (2023[55]), "Trade in value added", *OECD Statistics on Trade in Value Added* (database), https://doi.org/10.1787/data-00648-en, April 2022.

Since the 1990s, Korea's industrial strategy has become more technology-focused, and greater emphasis has been placed on the promotion of R&D and innovation (OECD, 2014[31]), which has led to the development of higher value-added tech products and exports. Considering R&D intensity, the share of mid-to-high-tech and high-tech exports has increased throughout the 2010s to nearly 70% of total manufacturing exports (Figure 2.18, Panel A). Among the three categories of high R&D intensity manufactured industries based on the OECD taxonomy (Galindo-Rueda and Verger, 2016[65]), Korea shows an unparalleled performance in computer, electronic and optical products (24% of total exports), which is almost triple the OECD average of 8.1% (Figure 2.18, Panel C), compared to the relatively negligible share of both aircraft and pharmaceuticals, although the latter has strongly increased since 2010 (Figure 2.18, Panels B and C). The strong performance in computer, electronic and optical products is mainly due to exports of semiconductors accounting for 20.1% of total exports in 2021. This followed the initial drop from 21.1% in 2018 to 17.6% in 2019 when semiconductor sales faltered globally, before recovering to 19.7% of total exports in 2020 as the global demand for at-home electronic gadgets increased. In 2021, the value of exports of semiconductors increased by 29% compared to 2020 (Statistics Korea, 2022[66]).

Figure 2.18. R&D industry exports in Korea and selected countries, 2010-20/21



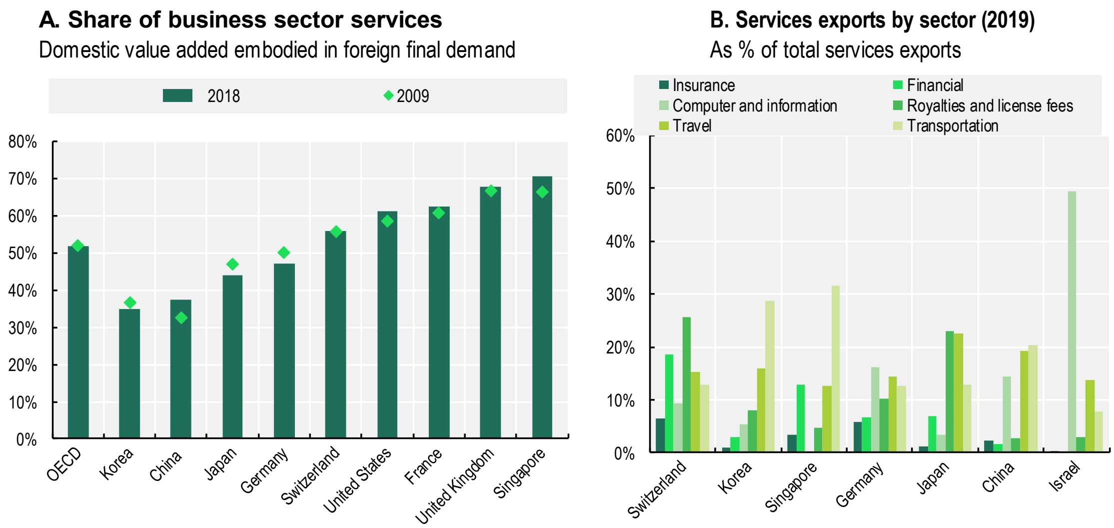
Note: Semiconductor and display industries in the first panel are singled out for significance. Other high-tech industries include pharmaceuticals, computers, telecommunication equipment, home appliances, precision instruments, batteries and aerospace.
Source: OECD calculations based on MOTIE Industrial Statistics Analysis System (ISTANS); OECD (2022[67]), *Trade in goods and services*, oe.cd/dp/4Bn; OECD (2023), Main Science and Technology Indicators (database), oe.cd/msti, (accessed on 23 June 2023).

On the other hand, Korea's exports of display panels gradually decreased from 10.4% in 2010 to 4.5% in 2021 (Figure 2.18, Panel A). During the same period, Korea's global market share diminished from 50.7% to 33.2% in 2021, mainly due to stiffening competition with Chinese manufacturers, whose share increased to 41.5% in 2021 (Korea Display Industry Association, 2022[68]). The TV set production supply chain has rotated among East Asian economies, whereby the market dominance has shifted from Japan to Korea, then again to China. China increased its dominance in liquid crystal display (LCD) panel production (63% of total production worldwide) over Chinese Taipei (21%), Japan (8%) and Korea (8%) (S&P Global, 2021[69]). As display panel producers are transitioning from LCD technology to organic light-emitting diode (OLED) technology driven by rising sales of smartphones and high-end televisions, Korea still excels on the technological front with 82.3% of global OLED market shares, followed by China (16.6%) (Omdia, 2022[70]) However, as the technological gap between Korea and China narrows, it may become increasingly difficult for Korea to secure its competitive advantage in the OLED display market (BusinessKorea, 2021[71]).

Despite rising competition, Korea's overall performance in the high-tech sector has been resilient, supported by the government's proactive policies and interaction with industry. In 2021, the government announced the National Strategy for Selection and Protection of National Critical Technologies[12] at the National Science and Technology Policy Coordination meeting presided over by the Prime Minister (Ministry of Science and ICT, 2021[72]). It lists ten core technologies[13] for which the government committed to establishing a proactive nurture and protection system to prevent the leakage of core skills and to strengthen inter-ministerial co-operation in both aligning strategies and integrating policies to be implemented. The strategy is backed by the government's pledge to increase R&D investment in these technology areas to KRW 3.3 trillion, its provision of a new Act on Special Measures for Strengthening and Protecting the Competitiveness of National High-tech Strategic Industries[14] in 2022 and by an amendment to the Special Taxation Act[15] to increase tax benefits for the firms' R&D costs and investment in infrastructures (Korea Law Information Centre, 2022[73]; Ministry of Government Legislation, 2022[74]). Furthermore, the Ministry of Trade, Industry and Energy (MOTIE) organised the first roundtable discussion with industry stakeholders in the semiconductor industry in an effort to establish a permanent communication platform with the industry. The discussion will likely be expanded to other sectors, such as automobiles, batteries and steel (Ministry of Trade, Industry and Energy, 2022[75]).

When considering service exports, the general trend among OECD countries since 2009 is that their share of domestic value-added embodied in foreign final demand has remained largely stable, around 52% (Figure 2.19, Panel A). Although largely stable when considering the average, a growing disparity emerges as countries that already had a larger share of value-added service exports, including the United States and Singapore, saw an increase between 2009 and 2018. Countries with a low share of business services in value-added exports, including Korea, but also Japan and Germany, have seen a further decline. Korea's share, with 35%, significantly lags that of countries leading in knowledge-intensive services, such as Singapore (70.5%) and other manufacturing-intensive economies, including Germany (47%) and Japan (44%). Moreover, despite employment growth in service sectors,[16] the share of value-added services has fallen, which implies that this growth occurred mainly in sectors with lower knowledge intensity, which is in line with findings from previous research (Park and Shin, 2012[56]).

Figure 2.19. Service exports in Korea and selected countries, 2009 and 2018



Source: Panel A: OECD (2023[55]), "Trade in value added", *OECD Statistics on Trade in Value Added* (database), https://doi.org/10.1787/data-00648-en, April 2022; Observatory of Economic Complexity (n.d.[50]), *Economic Complexity Rankings*, https://oec.world/, May 2022.
Panel B: Services classification follows United Nations Statistics Division (2021[76]), *Trade Statistics*, https://unstats.un.org/unsd/tradeserv/datacollection.htm.

The majority of service exports are in sectors with relatively low knowledge and technology intensity, such as transportation and travel, which, combined, account for almost 45% (Figure 2.19, Panel B). STI-related services that are being commercialised through royalties and licence fees are significantly lower (8%) than in other countries leading the innovation frontier. Royalties and licence fees constitute, for instance, a significant share of Swiss (25.5%) and Japanese (23%) service exports. Similarly, other knowledge-intensive services, such as financial as well as computer and information services, account for only 3% and 5.3%, respectively. These differences show that although Korea's economy belongs to the world's most complex ones, the country stands to benefit immensely from further diversification by expanding into knowledge-intensive services whose contributions to innovation through various channels are well documented (OECD, 2006[77]). Nevertheless, in some respects, knowledge-intensive service exports are growing in some areas, for instance, related to AI training and education. Knowledge-intensive services can carry a functional role as sources of innovation – where they are directly linked to innovation, such as in R&D or operational management – and act as facilitators of innovation, for instance, by helping a firm in the innovation process itself. In addition, they can serve as carriers for innovation in aiding knowledge transfer within and across organisations, networks and industries.

2.3. Korea can leverage its global position to strengthen its innovation performance

2.3.1. The reorganisation of global value chains holds implications for Korea

The analysis of global value chains (GVCs) is a useful tool for policy makers to comprehend the interconnectedness of economies. Analysing a country's embeddedness in GVCs allows the attribution of its export competitiveness to the sourcing of efficient inputs and access to final producers and consumers abroad (De Backer and Miroudot, 2013[78]). Active participation in GVCs allows countries to expand international specialisation and pursue economies of scale by reaching a larger customer base and allowing inter-regional knowledge spillovers. However, it also increases their vulnerability to supply and demand shocks.

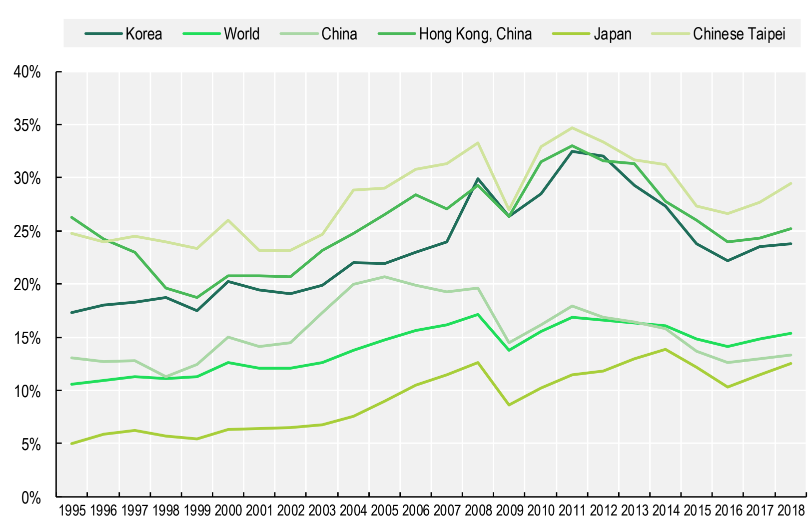
Recently, due to the disruptions in supply chains caused by the COVID-19 pandemic, the question of whether the gains from the embeddedness in GVCs outweigh the associated risks resurfaced (OECD, 2021[79]). During the crisis, firms temporarily stopped production at sites directly affected by the presence of the virus, and the economic shock was propagated along the value chains. A recent OECD report finds specific features that may determine the degree of exposure to shocks, which are: high reliance of sales on foreign demand; high dependence on foreign value-added in production; and high centrality of some "hubs" in GVCs (OECD, 2021[79]). However, these are the very characteristics that drive the benefits from GVCs by allowing the economies to specialise in their comparative advantage. No conclusive analysis exists of how GVCs will be reshaped in response to shocks, but the recent analysis suggests that GVCs are more likely to evolve further than to shut down (WTO, 2021[80]). Therefore, as the initial shocks caused by the pandemic recede, it is important to explore the policy options for Korea to minimise the shocks while continuing to reap the economic benefits from its GVC embeddedness.

Korea's participation in global value chains

Korea benefits from its active integration into GVCs. Three notable aspects of Korea's participation are its manufacturing industry's high reliance on foreign inputs and market demands, proximity to the global hub of China, and relative underperformance in the service sector trade. The first two are interlinked since GVCs, by nature, have a strong regional dimension.[17] For Korea, the short geographical distance to one of the world's biggest suppliers and buyers shapes the country's involvement along the value chains. The foreign value-added (FVA) content of gross exports[18] measures how much foreign inputs a country uses for exports. For Korea, the share declined from 39.7% in 2008 to 32% in 2018, which is, however, still higher than the OECD average and G7 economies' shares (Figure 2.20, Panel A). A high level of FVA is common for smaller countries and for countries engaging in high R&D manufacturing exports since they are dependent on intermediate inputs.

Figure 2.20. Foreign inputs for production in Korea and selected East Asian economies, 2008-18

Share of foreign value-added (FVA) content of gross exports



Note: The FVA content of gross exports measures how much foreign inputs a country uses for exports, while the global import intensity (GII) indicator measures the fragmentation of production by focusing on the imports needed to produce goods or services, whether exported or consumed in the domestic economies (Timmer et al., 2016[81]).
Source: OECD (2023[55]), "Trade in value added", *OECD Statistics on Trade in Value Added* (database), https://doi.org/10.1787/data-00648-en, April 2022; OECD (2022[82]), *OECD Inter-Country Input-Output (ICIO) Tables*, http://oe.cd/icio, April 2022.

This point becomes more evident on the regional level since Korea shows an import intensity comparable to small-sized economies such as Hong Kong (China) and Chinese Taipei and higher than Japan and China (Figure 2.20, Panel B). The global import intensity (GII) indicator measures the fragmentation of production by focusing on the imports needed to produce goods or services, whether exported or consumed in domestic economies (Timmer et al., 2016[81]). Miroudot (2020[83]) finds that all East Asian economies have witnessed a decreasing import intensity since the global financial crisis. However, the phenomenon is much stronger in Korea, where specific policies were implemented to encourage reshoring. Starting in 2013, subsidies and tax reductions were offered for relocating production to Korea, and in 2016, this was reinforced by a five-year tax exemption even for partial reshoring. Eleven sectors were defined as priority sectors, including robotics, self-driving cars, biotech and health-related products. In June 2020, the government went on to offer additional incentives to relocating high-tech companies, including subsidising relocation expenses, robotisation and automation of processes, tax exemptions and facilitation of visa requests by highly skilled immigrant workers. Such a reshoring policy focused on firms in specific sectors can be contrasted with policies focusing on the entire value chain in the home country, such as the French policy, and a policy of building a resilient value chain put in place as the “Supply chain resilience initiative” by Japan, India and Australia, which aims to reduce the dependency of value chains on China by creating alternate value chains based on trust and stability (Elia et al., 2021[84]).

Recent OECD findings on GVCs suggest a more comprehensive picture of Korea’s position within the GVCs. Foreign input reliance (FIR) and foreign market reliance (FMR) are useful indicators that measure, respectively, the country’s involvement in upstream activities and downstream activities. An upstream supplier exports intermediate goods, so the FIR index tends to be higher for the manufacturing industry, followed by services (Figure 2.21, Panel A). As a smaller and highly open economy, Korea relies to a larger extent on imported intermediates than large diversified economies. A majority of this intermediate depends on intra-regional trade, which confirms the findings from the above discussion on import intensity. On the other hand, Korea’s reliance on foreign markets is higher than in other economies, such as Germany, the United States and China (Figure 2.21, Panel B). As mentioned, the size of the economy matters, which explains Korea’s higher sensitivity to foreign demand than larger economies, but the level is found to be even higher when compared to those of country aggregates by regions. Also, Korea’s export destinations are largely centred in Asia and Oceania, and most notably, in China.

Moreover, trade in certain service sectors remains restricted. Overall, the OECD finds that Korea’s GVC income,[19] i.e. the sum of value-added generated by Korean firms along the global production chain from most service sectors, has significantly increased over the past 15 years. This shows the growing prominence of trade in services. However, this is driven by domestic demand rather than technological upgrades (OECD, 2021[85]). By the same token, when looking at the revealed comparative advantage[20] index by industry sector, other business services and information technology (IT) services show values above 1 (showing comparative advantage). Other sectors, such as finance and insurance, and telecoms, have values below 1 (showing no comparative advantage). Innovation and technology adoption relies on easier access to knowledge and networks of people, goods and services to share knowledge (OECD, 2021[86]). A clear identification of trade barriers in some services sectors deserves further policy attention for Korea to benefit more from open markets for services trade. Korea has made significant progress in service trade liberalisation, allowing its servicification to catch up with other OECD economies. However, barriers remain, such as foreign equity limits and complex registration procedures to establish a local presence (OECD, 2021[87]).

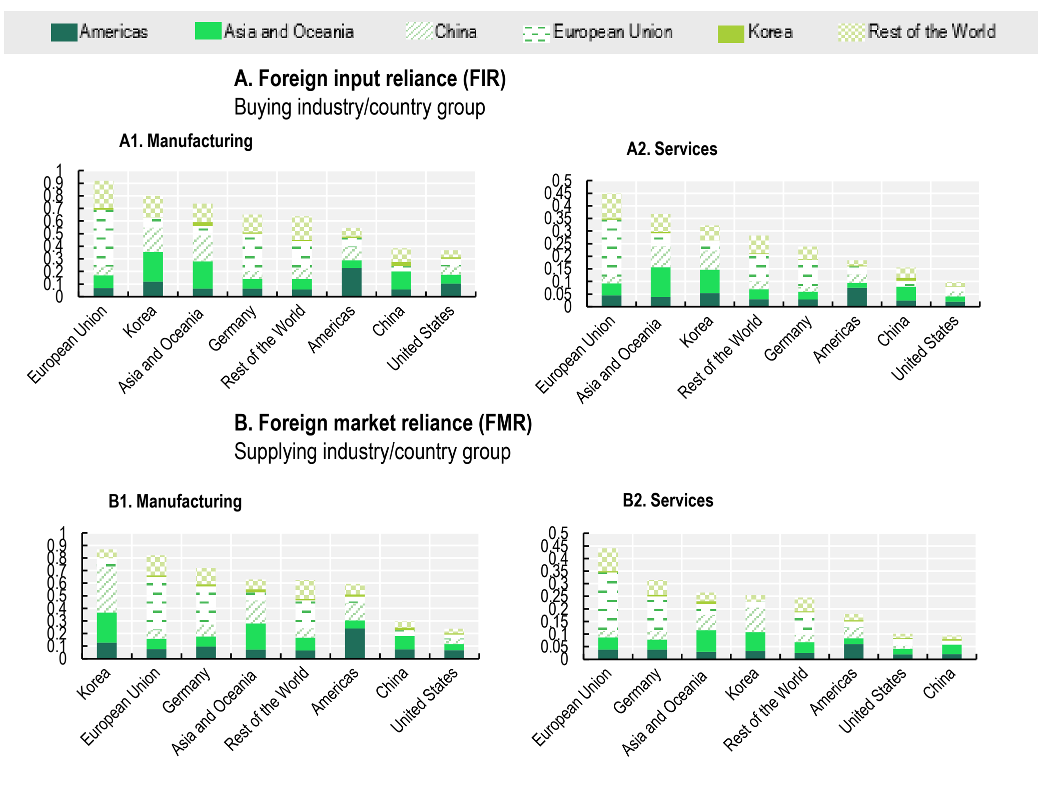
Policy objectives for Korea and the role of innovation policy

A range of public policies can be considered to enhance industry resilience against potential shocks. Although corporate decisions predominantly shape changes in GVCs, public policies can help align private and public interests and provide timely information to private companies to better estimate risks (Cadestin et al., forthcoming[88]). In this regard, the OECD (2021[85]) has recommended that Korea design a more inclusive GVC strategy to help it mitigate the impact of rising protectionism, reduce productivity gaps and promote business dynamism. Three policy objectives were proposed, namely:

- diversification of exports
- rebalancing productivity growth towards services
- mitigating the impact of protectionism and facilitating the reorganisation of GVCs.

These objectives still hold significance for Korea and other countries actively engaging in global trade. According to a more recent study by Cadestin et al. (forthcoming[88]), the first two objectives can be interpreted as an "adaptation strategy" since the government employs trade,[21] industrial, innovation and skills policies to help the economy rebound if a value chain shock materialises. These objectives can also be achieved by unilateral reforms in Korea rather than depending on the willingness of other trade partners (OECD, 2021[85]). The last objective, mitigation of the rise of protectionism and consolidating current trade agreements, can be seen as a "mitigation strategy"[22] since it aims to reduce the risk that a shock may occur in the first place.

Figure 2.21. Foreign input reliance and foreign market reliance in Korea and selected economies and regions, 2018



Note: In Panel A, each horizontal panel denotes a buying country (group), each bar a buying industry group, and the coloured stacks the contribution of the supplying country (group) to the FIR. In Panel B, each horizontal panel denotes a supplying country (group), each bar a supplying industry group, and the coloured stacks the contribution of the buying industry country (group) to the FMR. The contributions to the FIR are computed by: 1) aggregating to the level of the buying industry group *J* (agriculture, mining, manufacturing, services and total) in each country ($FIR_c^J = \sum_{j\in J}^{n}(FIR_{c,j} * W_{c,j}^{GO})$, where $W_{c,j}^{GO} = GO_{c,j}/\sum_{j\in J}^{n} GO_{c,j}$); and then 2) by aggregating to the level of the buying country (group) *C* (Americas, Asia and Oceania excl. China and Korea, China, Korea, the European Union and Rest of the World) as $FIR_J^C = (\sum_{c\in C}^{n} FIR_{c,J})/n$. A similar procedure is used to compute the contributions to the FMR.

Source: Schwellnus, C., et al. (2023), "Global value chain dependencies under the magnifying glass", https://doi.org/10.1787/b2489065-en.

Both supplier and buyer diversification and reshoring of selected production activities present interesting options for highly industrialised countries, including Korea. Diversification means redistributing trade links across countries without significantly modifying the overall value chain integration, therefore increasing the substitutability of inputs and export destinations. High diversification reduces global economic losses in response to disruptions and also lowers GDP volatility following productivity shocks (OECD, 2021[79]; Lan et al., 2022[89]). Korea has diversified its trade partners since the late 1990s, as is evident from its decreasing Herfindahl-Hirschman Index (HHI),[23] but the market remains relatively concentrated in selected countries compared to those of other economies (IIT, 2018[90]).[24] Overdependence on one trade partner may constitute a long-term risk, and diversifying export destinations, thereby increasing the substitutability of intermediate inputs, can ensure an economy's greater flexibility and resilience. In fact, Korea has been replaced by the Association of Southeast Asian Nations (ASEAN) economies in terms of high-tech intermediate goods exports as the internal demand of the Chinese market started to change rapidly (KITA, 2022[91]). In parallel, Korea can benefit further from trade preferences and common standards by joining mega-regional trade agreements (OECD, 2021[85]). Korea has already established a network of free trade agreements, but a majority of them are bilateral under different sets of rules. The new Yoon administration has established as one of the 110 national tasks to join new and benefit from existing multilateral trade regimes, such as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership and the Regional Comprehensive Economic Partnership (Government of Korea, 2022[92]). As opposed to bilateral agreements, these regimes would facilitate the creation of networks, help upgrade the GVCs and increase Korean firms' capacity (OECD, 2021[85]).

Meanwhile, disruptions wrought by the COVID-19 pandemic led many firms, mostly in the manufacturing sector, to become increasingly keen to alleviate the shocks in their supply chains by bringing back essential input production. Essential input production is also considered an alternative route – as opposed to diversification – since diversified trade linkages can increase the length and complexity of value chains. Despite the saliency and attractiveness of this option, however, the economic cases for reshoring GVCs are still relatively weak, and using a range of government policies to better structure firm production processes presents a better option (OECD, 2021[79]).

In terms of encouraging productivity growth towards services, Korea could consider more actively adopting disruptive technologies in the production process and strengthening the SME and start-up sector through innovation policies. Successful absorption of new technologies has been proven to increase productivity and encourage structural transformation. (OECD, 2017[38]). The set of cutting-edge technologies is broadly referred to as Industry 4.0, and their impacts vary across industries. More labour-intensive industries are less vulnerable to changes, whereas mid-to-high-tech industries (e.g. electrical and electronics and machinery sectors) are likely to be affected to a greater extent. In advanced, industrialised countries with a strong manufacturing base, such as Korea, such changes, therefore, have great implications. As the average population age and labour costs increase, the capital intensity of the production process is expected to grow (Frederick et al., 2017[93]).

Furthermore, adopting new technologies is generally an investment-intensive process that stretches far beyond capital input. Therefore, it needs to be complemented with relevant expenditures, such as through firms' investments in technologies and by ensuring the well-functioning of tertiary-level educational institutions in science, technology, engineering and mathematics (STEM) disciplines. Overall, Korea's high R&D intensity, high level of educational attainment and strong emphasis on STEM disciplines show that it is well-positioned to adapt to such changes. However, firms' absorptive capacities for new technologies need to be enhanced. In parallel, in order to ensure economy-wide resilience, it is critical to promote the growth of innovative SMEs and start-ups. Innovation policies can encourage the emergence of innovative firms in strategically important sectors in the wake of sudden demand surges and supply shortages (Cadestin et al., forthcoming[88]). Currently, the ratio of innovative firms in Korea is the lowest among OECD countries (Figure 2.11), and SMEs' overall low productivity may signal their lack of innovative capacities.

2.3.2. Foreign direct investment restrictions remain relatively high in some sectors

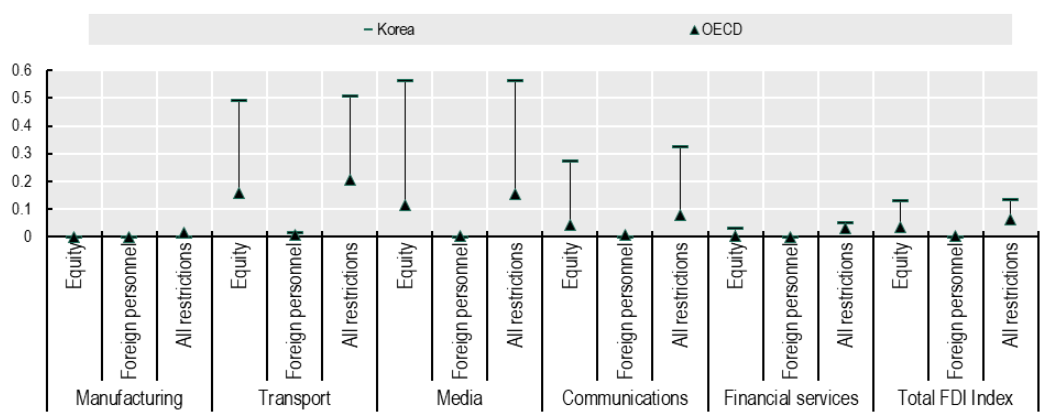
Foreign direct investment (FDI) by multinational corporations (MNCs) has various benefits for the host economy, including productivity growth, knowledge spillovers, industry diversification and service sector growth (Xiaolan, Emesa and Hou, 2021[94]). It allows new technology to be diffused, especially by SMEs with high absorptive capacity and if a country is attracting investment into knowledge-intensive sectors. A proactive STI policy can also be a powerful driver of FDI by knowledge-intensive firms wishing to benefit from local knowledge. Indeed, a strong local STI system can provide specific knowledge inputs to knowledge-intensive firms.

Korea demonstrated a particularly strong commitment to market liberalisation in the 1990s. The corresponding reforms entailed the reduction of trade barriers as well as fewer restrictions on FDI. Following its accession to the OECD in 1996, Korea has driven the most transformative FDI liberalisation progress among OECD countries, as measured by the OECD FDI Regulatory Restrictiveness Index.

Nevertheless, in 2020, Korea was still the sixth-most restrictive OECD country when it came to FDI. While hardly any trade and investment restrictions apply to the manufacturing sector, some service industries, such as telecommunications, pose conditions including foreign equity limits of 50% (Figure 2.22). Moreover, public procurement regulation in some ICT services allows for preferential treatment in favour of Korean small and medium-sized businesses and requires foreign companies to create a local presence to provide their services, subject to a costly company registration, thus creating a barrier to foreign suppliers.

Figure 2.22. FDI Regulatory Restrictiveness Index, Korea, 2019

For a selection of restrictions and a selection of sectors

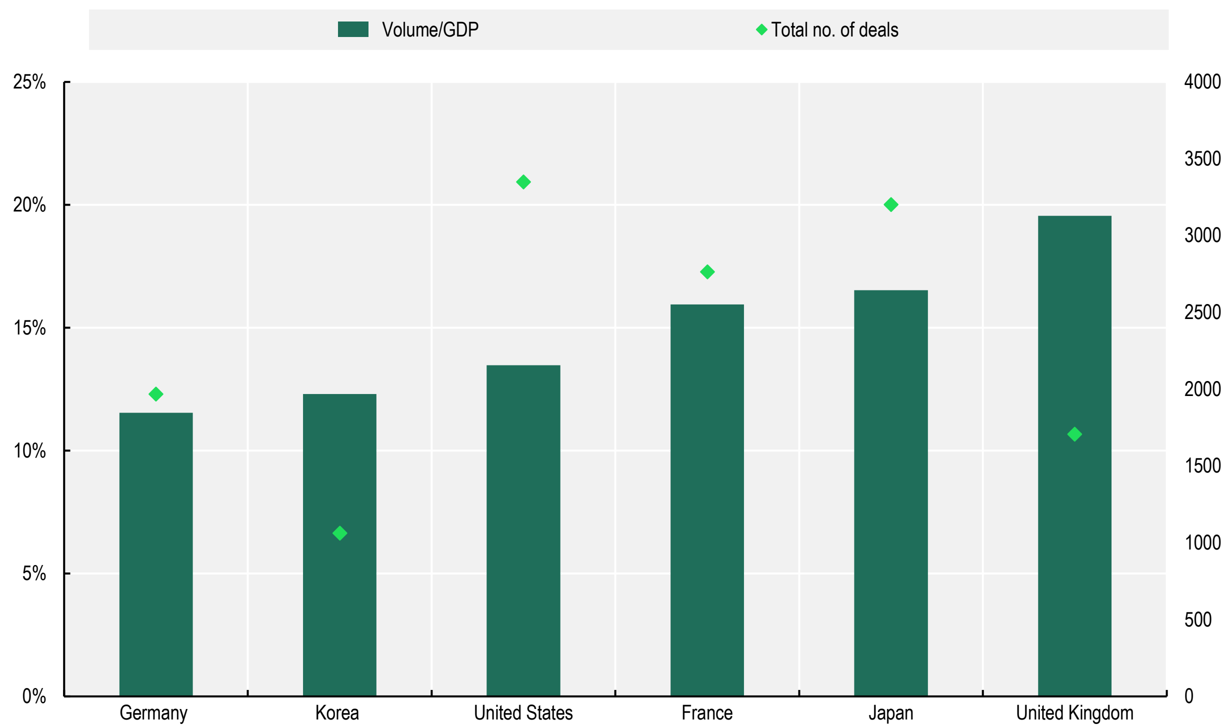


Source: OECD (2022[95]), *FDI Regulatory Restrictiveness Index*, https://www.oecd.org/investment/fdiindex.htm.

In the years following the Asian financial crisis leaving many firms in need of capital, inward FDI has more than quadrupled, notably in the form of mergers and acquisitions (M&As) and joint ventures. This has been a positive development for Korea since firms and industries with larger FDI inflows show higher average labour productivity, wages and R&D spending. FDI was found to have contributed significantly to the country's trade surplus, employment generation and manufacturing sector (OECD, 2021[87]). Furthermore, international linkages, such as joint ventures, tend to foster knowledge transfer from foreign to domestic firms. However, FDI inflows have since stagnated in recent years, reaching 0.6% of Korea’s GDP in 2019 compared to 1.2% for the OECD average.

Among OECD innovation leaders, Korea had the lowest total number of M&A deals between 2012 and 2022. In contrast, measured in terms of total volume as a percentage of GDP, Korea’s share of M&A deals is 12.3%, slightly higher than Germany (11.54%) and considerably lower than other comparator countries, including Japan (16.52%) and France (15.95%) (Figure 2.23). More specifically, Korea's M&A deals took place mostly in established industries, notably in industrial materials. In all other countries, there was a more even share of existing and emerging sectors, with the latter including healthcare and communications. A key restriction with regard to M&A applies to emerging SMEs, which are acquired by or incorporated into conglomerates, as these consequently become subject to holding company regulations and lose access to affiliate support (FKI, 2022[96]).

Figure 2.23. Total volume and number of merger and acquisition deals in Korea and selected countries, 2012-22



Source: Federation of Korean Industries (2022[97]), *M&As slow in Korea due to tight regulations: FKI*, https://www.koreaherald.com/view.php?ud=20220210000704.

2.3.3. Despite a relatively open policy on attracting international students, Korea's appeal as a migration host destination is low

International mobility of students, researchers and skilled workers can contribute positively to a country's innovation system in various ways, such as a higher population size increasing the prevalence of innovative talent, complementary skill composition, which reduces labour market mismatches, and more diversity spurring creativity. Moreover, knowledge spillovers from foreign, high-skilled labour, as well as tacit knowledge, which returning nationals "carry" back to their origin country, are common drivers of innovation (Xiaohui Liu, 2010[98]).

Korea has committed to a comparatively open talent immigration system with numerous initiatives to promote inflows of foreign researchers and students. For instance, it has introduced the following ongoing initiatives:

- BrainKorea21 entails a scholarship programme for international students.
- The Gold Card Visa programme offers visas with longer durations for skilled labour in advanced technology.

- The Global Korea Scholarship programme is a fully-funded scholarship programme for international undergraduate and graduate students to study in Korea.

These initiatives were launched in 1999, 2000 and 1967, respectively, to attract international researchers and students to foster Korea's shift to a knowledge-based economy. As a result, the share of foreign tertiary student inflows as a percentage of total enrolled students increased by 80% between 2010 and 2019 (Figure 2.24, Panel A). Nevertheless, in 2021, more than two-thirds of foreign students came from either China with 44% (down from 71% in 2010) or Viet Nam with 24%. Furthermore, these increases occurred from relatively low levels; Korea still has one of the lowest shares of foreign students among OECD countries. On the other hand, a relatively high share of Korean students opts to go abroad for their studies, with a share of 3.4%[25] of outflows of all domestic students, much higher than Japan (0.9%) or the United Kingdom (1.8%) and just below Germany (4%) and France (4.1%).

In addition, the inward mobility of foreign researchers remains low. The share of international scientific authors' net inflows as a percentage of total authors is 1.6%, among the lowest in the OECD (Figure 2.24, Panel B). This prevents Korea from tapping into other sources of inspiration and new ideas for innovation, which skilled foreign labour and international research co-operation can offer. Inflows of foreign researchers and professionals remain low despite historically open immigration policies and reductions in barriers for skilled employees in recent years. Very few foreigners choose the path towards permanent residence even though Korea has one of the most generous job-search visas among OECD countries (OECD, 2019[99]).

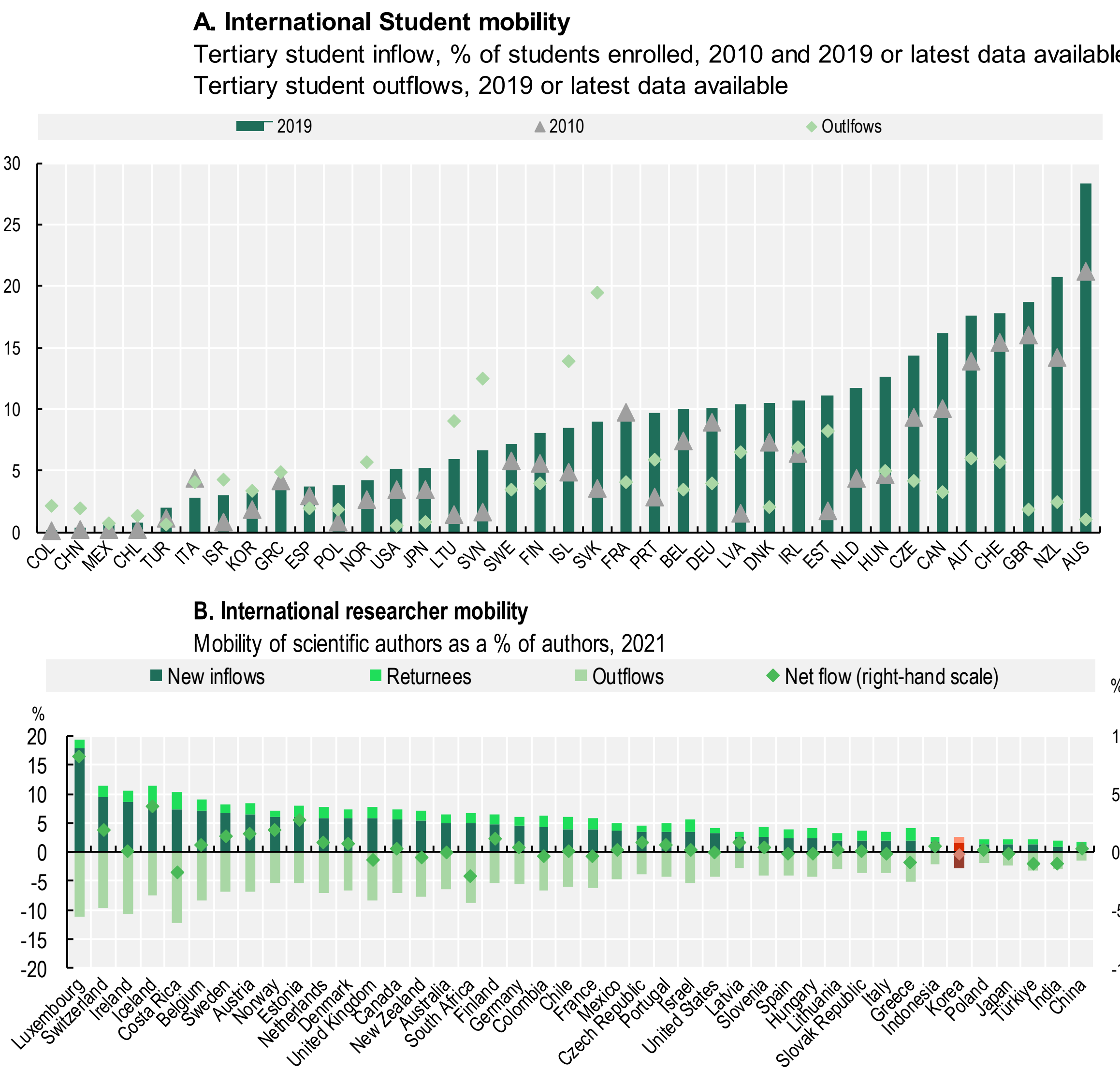
In 2003, Korea launched one of the largest temporary employment permit systems in the OECD, both in absolute terms and relative to the labour force, one of whose objectives was to better meet SMEs' needs for semi-skilled employees as well as to create a points-based system that allows entry for foreign talent based on the fulfilment of criteria as pertains to education, age, Korean language skills and income. Furthermore, MOTIE launched a global recruitment service, Contact Korea, in 2008 to recruit foreign workers for SMEs. Other initiatives, including job fairs abroad and contests to appeal to high-skilled international professionals, in particular for start-ups, have been undertaken under various schemes (OECD, 2019[99]).

Overall, the migration framework has been continuously adapted to welcome foreigners; however, crucial factors prevent foreigners from wanting to stay for the long term, including working conditions and strong hierarchies, gender disparity, a highly competitive tertiary job market, difficulties in enrolling their children in the education system as well as closed social networks (Kraeh, Froese and Park, 2015[100]; Shin and Choi, 2015[101]). In order to appeal to foreign skilled immigrants, change needs to occur in culture rather than policy (Herting, 2016[102]). For instance, there was a strong increase in foreign professors joining Korean universities until 2012, which was largely interpreted as a commitment to and success of highly skilled immigration. However, while increasing the number of Western faculty members does well for rankings, in practice, they are often deprived of power and marginalised, frequently being positioned in isolated colleges with low impact, as pointed out in stakeholder interviews. In some cases, missing or minimal socialisation with Korean colleagues has also meant that expatriate professors were not asked to serve on faculty committees. The absence of such faculty activities, in turn, has resulted in the rejection of their applications for tenure (Park, 2018[103]). This lack of integration has resulted in many professors leaving after their period of assignment only to be replaced with new recruits. This is particularly detrimental in view of foreign professors being more productive than domestic ones, thereby inhibiting harnessing the full potential internationalisation can offer.

Having skilled immigrants join the local labour force could spark new ideas, knowledge diffusion and the creation of new businesses as they tend to be bigger risk takers. Moreover, immigrants provide a culturally diverse view on business models and value propositions, which could help Korean start-ups internationalise rather than remain local players. In addition, Korean SMEs that face serious technical skills shortages could leverage skilled immigrants' tech savviness and entrepreneurial spirit to promote productivity through the scale-up of digital technologies. Current policy requires foreigners without university degrees to have at least five years of work experience.

Immigration will become all the more relevant in light of population ageing and the decline of the labour force of the Korean economy. This demographic change is one of the critical societal challenges set to affect Korea going forward.

Figure 2.24. International student and researcher mobility in Korea and selected countries, 2019



Source: Panel A: OECD (2022[104]), *Education Statistics* (database), oe.cd/dp/4Bt, May 2022. Panel B: OECD (2022[24]), *Main Science and Technology Indicators* (database), oe.cd/msti,, May 2022.

2.4. Societal challenges put Korea’s innovation system under pressure

The 2030 Agenda for Sustainable Development was adopted in 2015 and set out an ambitious action plan with 17 Sustainable Development Goals (SDGs). By 2021, Korea had achieved 28 of 128 targets related to securing basic needs and implementing necessary policy tools and frameworks mentioned in the 2030

Agenda. As one of the best-performing countries in industry and innovation, Korea's strengths lie in the goals of the Prosperity category (Goals 8, 9, 11),[26] where they are also above the OECD average (OECD, 2022[105]). On the other hand, Korea faces challenges in promoting inclusion and equality in society (Goals 1, 5, 10).[27] This reflects the high relative income poverty, under-representation of women in workplaces and existing legal and financial frameworks not being able to adequately tackle the issues of inequality.

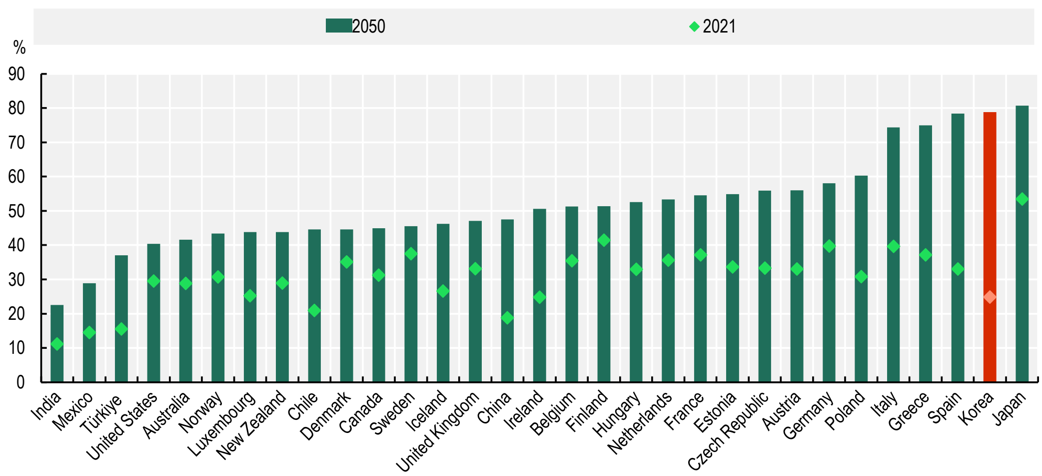
Korea has continued its efforts to incorporate the SDGs into its national development plans. The first Framework Act on Sustainable Development dates back to 2006, which led to the first Basic Plan on Sustainable Development (2006-11; hereafter, the "SD Basic Plan"). The legal basis for the SD Basic Plan was changed to the Framework Act on Low Carbon Green Growth, which was adopted in 2010. Since 2011, the SD Basic Plan was renewed twice every five years until 2020. In 2018, the national SDG goals ("K-SDGs") were established in 17 fields (goals), with 122 specific targets and 214 indicators (currently amended to 119 targets and 236 indicators) as complementary to the United Nations SDGs (Ministry of Environment, 2022[106]). Setting the K-SDGs was largely a bottom-up process, and more than half (57%) of the 122 targets address societal concerns specific to Korean circumstances. The fourth SD Basic Plan covers a longer period of 20 years (2021-40). Under the vision of "building a sustainable nation through inclusiveness and innovation", it establishes four thematic strategies (people, prosperity, environment, peace and co-operation) supported by 17 goals. For the last decade, special attention has been given to incorporating SDGs into national policies and plans to make them more compatible with the existing framework conditions in Korea on issues such as ageing, gender equality and environmental protection (United Nations, 2016[107]).

2.4.1. Korea is expected to have the steepest rise in old-age dependency by 2050

As is the case for many industrialised economies, Korea faces a significant increase in its old-age population outside the labour force. By 2050, it is expected to have the second-highest dependency ratio after Japan, which means that its old-age population above the age of 65 relative to the population in the labour force supporting the pension systems will be very high, with about 80% of the labour force, which is roughly on par with Japan (Figure 2.25). More specifically, however, the rise is expected to be the highest among OECD countries from 2021 levels of 23%, compared to 53% for Japan, for instance, where the rise will be slower, allowing policies and the economy to adjust more gradually. For Korea, the drastic shift has vast implications for the labour market, its national innovation system and the economy more generally. The impact on the talent pool is already visible, with a lack of young people leading to fewer student enrolments at some universities, notably in regions outside the metropolitan areas, potentially forcing some to close down. Moreover, this will pressure firms, especially SMEs, to secure talent for their business operations from a shrinking pool of available candidates.

This further underlines the importance of leveraging the prevalent skills-based immigration system in line with the needs of businesses, thus compensating for the increasing lack of human capital. Since the policy framework is largely in place, efforts to better integrate immigrants so as to increase Korea's appeal as a migration host destination will be of particular relevance.

Figure 2.25. Old-age dependency by 2050, Korea and selected countries

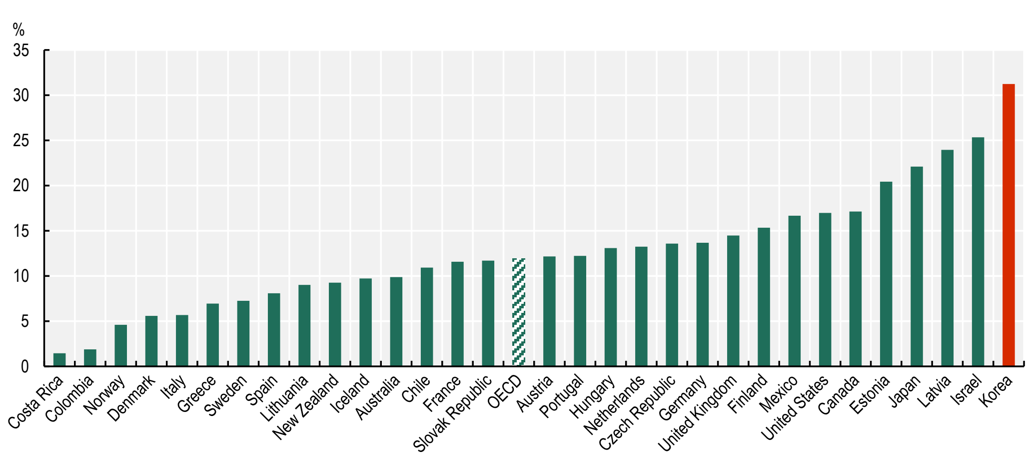


Note: The old-age to working-age demographic ratio is defined as the number of individuals aged 65 and over per 100 people of working age, defined as those aged 20-64.
Source: OECD (2023), "Old-age dependency ratio" (indicator), https://doi.org/10.1787/e0255c98-en (accessed on 23 June 2023).

In addition, Korea has the highest gender wage gap among OECD countries (Figure 2.26). A major reason for this is the high opportunity cost of having children. Long working hours, concerns over the quality of childcare and societal norms around gender roles contribute to the cost for women in combining having children and a career. In addition, hiring practices are heavily based on seniority, meaning that career breaks for child-bearing purposes significantly hamper women's employment trajectories. More specifically, women re-entering the labour market after parental leave often do so as non-regular employees in jobs with considerably lower wages. Moreover, many women may be reluctant to have children in the first place due to perceived difficulties in returning to work afterwards. Such behaviour may further lower overall fertility. To increase mothers' rates of returning to work after a career break and to decrease the opportunity cost of having children, the government is providing vocational and other education and training programmes through specific job centres and training by the Ministry of Employment and Labour and the Ministry of Gender Equality and Family.

Figure 2.26. The gender wage gap in Korea and selected countries, 2022

2022 or latest data available



Source: OECD (2022[108]), *Employment and Labour Market Statistics* (database), oe.cd/dp/4WZ, May 2022.

Other judicial and policy initiatives to address the issue of population ageing have been established to alleviate social and economic insecurities for people across the various stages of life. They include the Plan for Aging Society and Population (2015), the Framework Act on Low Fertility and Population Aging (2014), and the Law for Promoting Elderly-Friendly Industries (2013).

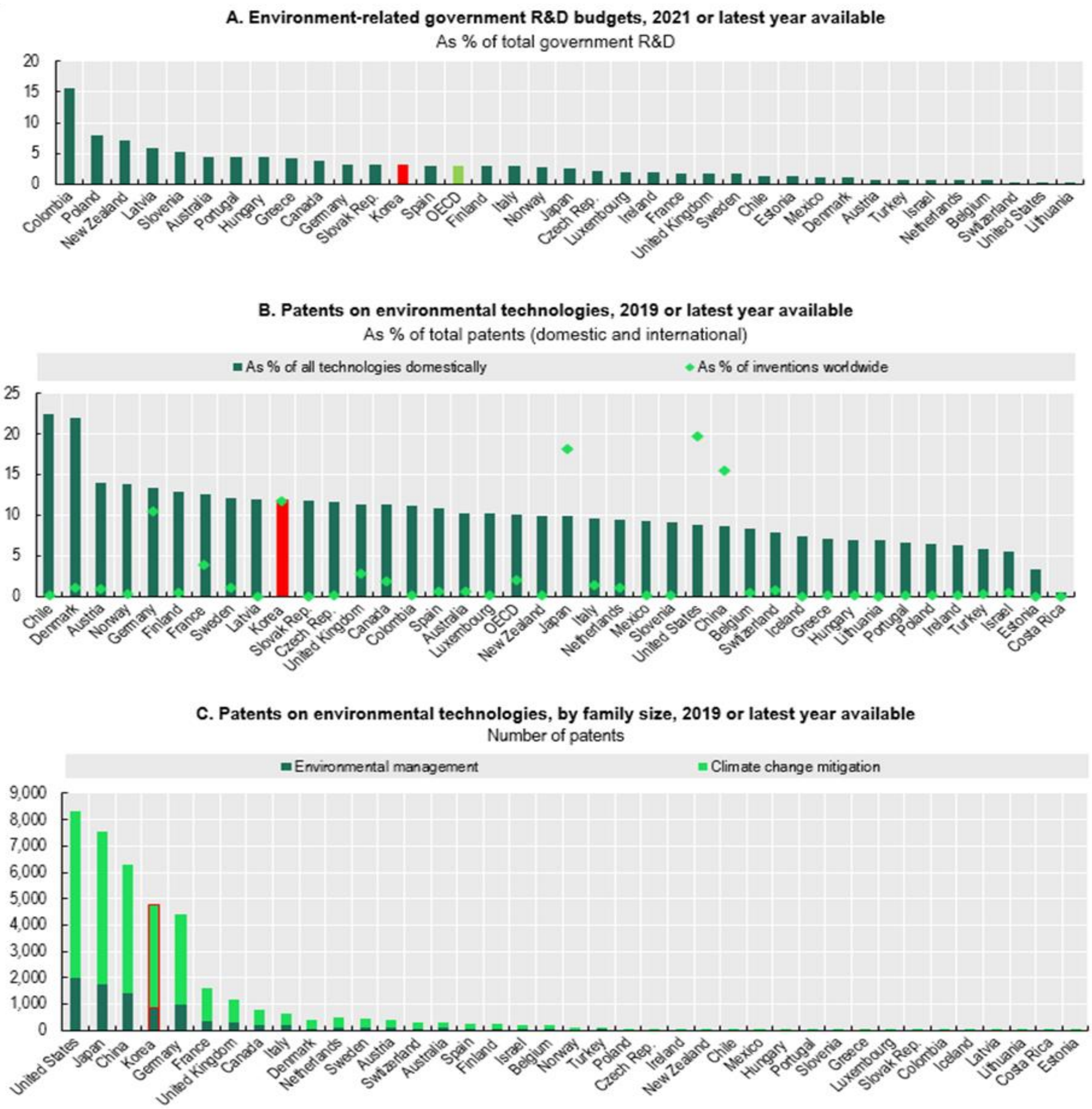
2.4.2. Following previous efforts, which leave room for improvement, Korea has adopted policies to tackle climate change, but implementation will depend on wider participation from both society and industry

Climate change is a global concern that affects ecosystems and diversity and generates considerable socio-economic consequences. Globally, apart from a few countries, there has been a decoupling of greenhouse gas (GHG) emissions from GDP and population growth, and emission intensities per GDP have decreased since 2007 across most OECD economies (OECD, 2022[109]).

Korea is working towards its climate neutrality target. Korea ratified the Kyoto Protocol and the Paris Agreement as an expression of commitment to join international efforts in fighting climate change. The government recently revised its reduction target to 40% of the 2018 level by 2030 from its previous goal of 26.3% submitted in 2020. The new administration supports this goal and plans to expand nuclear power generation to accelerate the country's goal of zero emissions. It has also anchored several policies that propel nationwide green transition, such as the National Green Growth Strategy (2009-2050), Five-year Plans for Green Growth (third in 2020) with detailed investment plans and tasks for the ministries and local governing entities, and the Framework Act on Low Carbon, Green Growth (2010). In 2015, Korea introduced the third-largest emission trading scheme (K-ETS) after the European Union's Emission Trading System (EU ETS) and China. Currently, Korea has one of the widest (73%) sector coverage in terms of types of economic activities[28] (International Carbon Action Partnership, 2022[110]). However, carbon prices are much lower than in other countries. The auctioning revenue from emission trading as a source of government revenue is rather modest at USD 199.4 million since 2019, compared to USD 8 497 million in Germany and USD 5 928 million in the United Kingdom since 2021. Furthermore, innovation is considered a key pillar in leading Korea's green transition. High investment levels in R&D place Korea in a favourable position for transforming itself into a carbon-neutral economy. The government allocates a higher R&D budget for environment-related programmes and projects than the OECD average (Figure 2.27, Panel A). Korea is one of the most innovative countries in developing environmental technologies, particularly climate change mitigation technologies (OECD, 2017[111]) (Figure 2.27, Panels B and C).

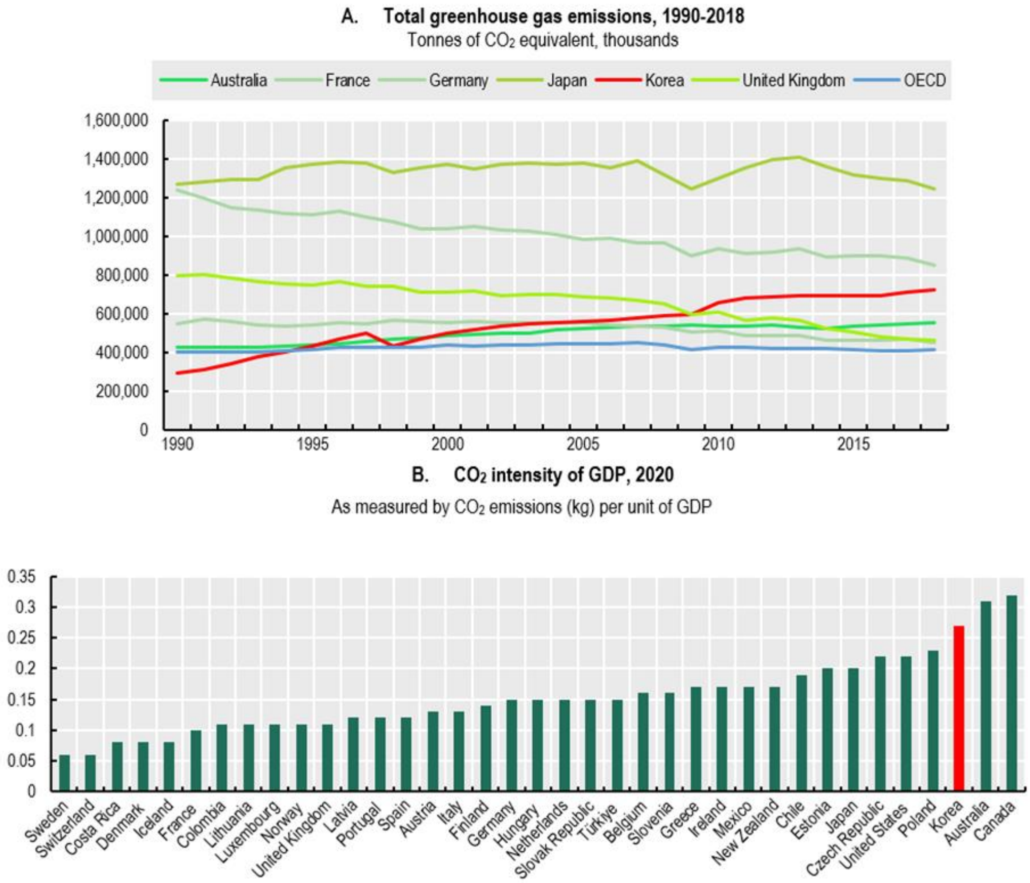
However, total emissions (Figure 2.28, Panel A) indicate that past and current policy initiatives, as well as Korea's innovation performance, have been insufficient to generate the needed structural changes. After incurring the steepest rise in GHG emissions between 1990 and 2005, the government made the commitment to reduce its emissions by 30% below the "business as usual" (BAU) baseline by 2020. *De facto,* this would imply a 4% reduction from 2005 levels; however, actual emissions have risen from 560 million to 728 million tonnes in the given period, an increase of 30%. A study by Kalinowski concludes that despite ambitious green growth policies being implemented, "Korea's legacy as a developmental state characterised by strong corporatist links between state and business as well as a weak civil society" explain the underperformance in emissions mitigation. The ambition was amended in 2015 to a reduction of 37% below BAU while extending the deadline to 2030 (Kalinowski, 2021[112]). In addition, Korea's carbon dioxide intensity of GDP remains one of the highest among OECD countries (Figure 2.28, Panel B).

Figure 2.27. R&D budgets for environment-related programmes and patents on environmental technologies in Korea and selected countries, 2021 and 2019



Source: OECD (2022[116]), *Green Growth Indicators*, oe.cd/ds/4BK, June 2022; OECD (2022[117]), *Intellectual Property (IP) Statistics and Analysis*, oe.cd/4BL, June 2022.

Figure 2.28. Greenhouse gas emissions (1990-2018) and CO_2 intensity of GDP (2020) in Korea and selected countries



Note: Panel A: Total emissions excluding land use, land-use change and forestry. Panel B: 2019 data for Costa Rica.
Source:
Panel A: OECD (2022[118]), Environment Statistics (database), oe.cd/dp/4BM, June 2022.
Panel B: OECD (2022[116]), Green Growth Indicators, oe.cd/ds/4BK, June 2022.

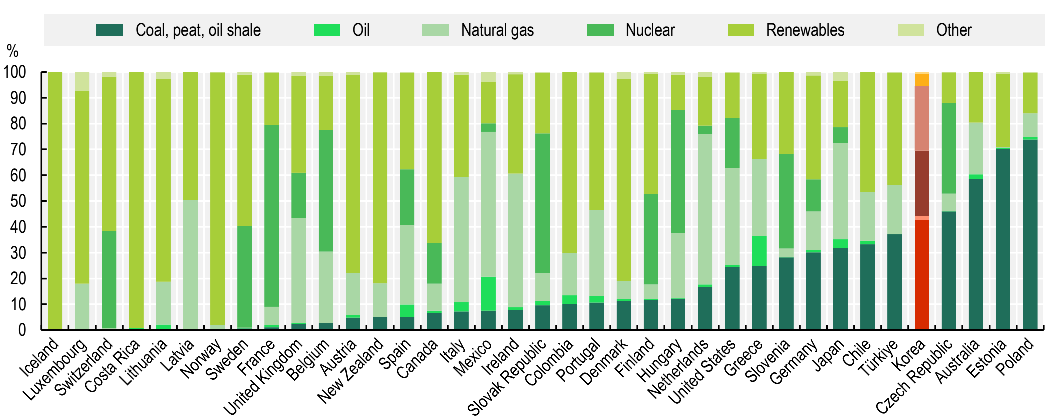
One bottleneck may be the lack of public engagement. Achieving a climate neutrality goal depends on whether or not a government can attract and incentivise broad-based participation from society and industry. In fact, Korea benefits from a relatively high level of public awareness around the need for the green transition (Dechezleprêtre et al., 2022[113]) (OECD, 2022[17]). According to the OECD Economic Survey (OECD, 2022[17]), most Koreans agree that climate change is an important problem and will negatively affect their personal lives. Concrete policy measures receive moderate support; for instance, only around half of a surveyed group supports a tax on fossil fuels. However, Korea outperforms Germany in this regard, on par with the United Kingdom and Denmark. Accumulation of knowledge on climate change needs to be paired with society's acceptance of laws and a co-operative attitude among citizens to bring substantive impact (Willems and Baumert, 2003[114]). Benefiting from a high level of public awareness around climate policies, Korea can bolster further engagement from its citizens to materialise its policy ambitions. For instance, the 2017 Green New Deal initiative is the largest policy package (KRW 114 trillion) in Korean history to make the economy greener (see Chapter 5). However, according to a survey conducted by the Korea Environment Institute (KEI) under the Ministry of Environment, over half (58.5%) of respondents stated that they are neither knowledgeable nor have heard of the concept of the Green New Deal, and 41.6% considered the policy "unrealistic" (KEI, 2021[115]).

Another bottleneck may be that Korea aims to reduce GHG emissions in a cost-effective way (IEA/KEEI, 2022[119]) but does not fully leverage the emission trading system. The power sector, i.e. the generation of electricity and heat, is the largest source of emissions in many OECD economies, including Korea (58% of total carbon emissions), and the International Energy Agency (IEA) Net Zero 2050 Roadmap designates it as the first sector to decarbonise (IEA, 2021[120]; International Carbon Action Partnership, 2022[110]). Currently, the electricity market in Korea is highly coal-intensive (fifth among OECD countries), generating 38.7% of the country's electricity from coal (Figure 2.29, Panel A). From 2010 until 2020, coal's share decreased by 5.2%, but gas rose by approximately the same margin (5.2%), meaning that the total generation from fossil fuels changed very little (-2.8%). In the meantime, the growth of renewable sources was rather muted, indicating that Korea's energy market has remained invested in non-renewable sources for the past decade (Figure 2.29, Panel B). Carbon pricing can be a very effective policy to make low- and zero-carbon energy more competitive (OECD, 2021[121]) by sending the right signals to the demand side.

Figure 2.29. Electricity generation by source and share of renewable energy in Korea and OECD countries, 2020

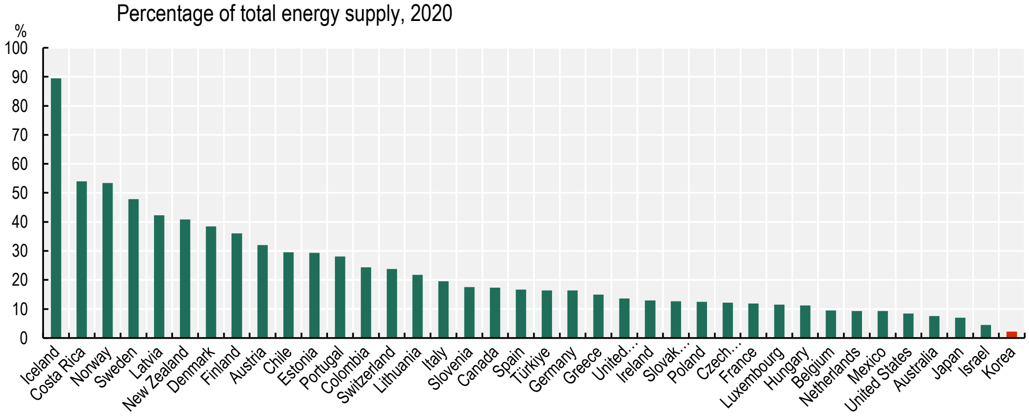
A.Energy mix in electricity production

Shares in total electricity production, 2020 or latest year available



B. Renewable energy supply

Percentage of total energy supply, 2020



Note: Panel A: In the legend, "Hydro, bioenergy and other renewables" is an aggregate of biofuels, hydro, waste, tide, geothermal and other sources, and "Wind and solar" is an aggregate of solar PV, wind and solar thermal. All are based on the IEA classification. Panel B: Renewable energy is defined as the contribution of renewables to the total primary energy supply (TPES). Renewables include the primary energy equivalent of hydro (excluding pumped storage), geothermal, solar, wind, tide and wave sources. Energy derived from solid biofuels, biogasoline, biodiesels, other liquid biofuels, biogases and the renewable fraction of municipal waste are also included.

Source: Panel A: IEA, "World energy statistics", *IEA World Energy Statistics and Balances* (accessed on 27 June 2023).

Panel B: OECD, "Green growth indicators", *OECD Environment Statistics* (database), https://doi.org/10.1787/data-00665-en (accessed on 27 June 2023).

However, the explicit carbon price in Korea (approximately USD 10.5/tonne)[29] has remained far below the level required by 2020 to be consistent with the Paris Agreement (USD 40-80/tonne). In 2030, the European Commission estimates that the price should reach USD 50-100, provided that a supportive policy environment is in place, meaning complementary action needs to be taken through other policy instruments, e.g. adjusting the cost of transition and increasing political and social acceptability of the carbon price. Apart from the price of carbon emissions, the overall effectiveness of the K-ETS system has been unclear to date. Narassimhan et al. (2018[122]) find that by international comparison, Korea's 100% free allowance allocation approach[30] at the firm level and the minimal increase in auctioning compromise the credibility of K-ETS. Generally, the marginal costs of carbon dioxide tend not to be taken into account by private actors when deciding how much to produce or consume (Butner et al., 2020[123]). Within the European Union, industry sectors facing carbon leakage tend to receive higher shares of free allowances[31] (European Commission, 2022[124]), in part to secure industry competitiveness. Furthermore, in Korea, the ETS cap has been questioned for relying too heavily on a bottom-up approach where the manufacturers derived the abatement targets, whereas the societal and environmental aspects have been relatively disregarded (Kim, 2015[125]).

Some criticise the Green New Deal for laying out the net-zero carbon emission target by 2050 without specific responsibilities, targets or actions to follow to that effect. The only emission target mentioned of a reduction by 16.2 million tonnes is below the "2030 National Greenhouse Gas Reduction Implementation Plan" introduced in 2018. This stands in contrast to the European Union Green Deal, which sets out near-time and binding objectives and monitors compliance by private entities (Woo, 2020[126]). While the Green New Deal and other government initiatives reflect Korea's aspirations to become a green leader and show strong investments in green technologies, the path dependencies of the developmental state involving strong business-government affiliation hinder progress when it comes to reducing emissions and, therefore, imposing higher costs onto businesses. In combination with a relatively restrained civil society, this enables the private sector leeway to assert their mostly near-term profit-oriented interests (Kalinowski, 2021[112]). In fact, carbon emissions in Korea are estimated to have been around 679.6 million tonnes in 2021, according to recent data, which is a 3.5% increase over the previous year. Emissions by the top 30 private companies have increased by 4.2%, reaching a new all-time high (Ministry of Environment, 2022[127]).

Nevertheless, co-operation with and buy-in from the private sector is essential in mobilising resources, knowledge and innovation for addressing climate change (OECD, 2016[128]). Business practices are often associated with environmental pollution and degradation, and possibly to a greater extent in Korea, considering the country's larger coal-intensive industries. Private firms can also, however, play a critical role in promoting green behaviour across supply chains, increasing investments in clean infrastructures and leading innovation in clean technologies. Given the policy trend, conglomerates in Korea have announced their commitments to emission-reduction targets by 2030 and joined global initiatives, such as RE100 (Kim, 2020[129]; RE100, 2021[130]). In 2021, 10 conglomerates[32] formed a hydrogen alliance, vowing to provide an additional 1 500 hydrogen-powered electric cars; expand hydrogen charging infrastructures; and establish a hydrogen energy council in the private sector (IT Chosun, 2021[131]). Hyundai-KIA is gaining global market share in electric cars (KATECH, 2022[132]), and offshore wind power installations also have proved a promising business opportunity for the top three firms in the Korean shipbuilding industry (Hankyung Economy, 2022[133]). Moreover, Korea's steel group, POSCO, also the biggest carbon emitter, committed to replacing coal with hydrogen in its steel production system by 2027 (The Korea Times, 2022[134]). POSCO is also co-operating with the world's biggest steel manufacturers, such as Nippon Steel of Japan and SSAB/LKAB/Vattenfall of Sweden, to develop new technologies that are not yet proven at scale.

However, it is unclear whether this private sector push will materialise in a breakaway from the traditional profit model, given that the highest-emission industries in Korea are the most successful ones. Private sector resistance has been strong, and already before the introduction of the K-ETS system in 2015, the

Federation of Korean Industries (FKI), a non-profit organisation that consists of Korea's major conglomerates and associated members, expressed grave concern about the possible compromise of industry competitiveness (FKI, 2014[135]). Since then, the K-ETS system has demonstrated encouraging results in this respect, as carbon-intensive industries have increased their corporate carbon productivity at the firm level[33] (Jung et al., 2021[136]). However, the recently announced K-ETS Phase 3 allocation plan (2021-25) is likely to face a similar level of headwinds from industry since it contains stricter provisions, such as a tightened power sector benchmark, updated allocation provisions (e.g. a rise of the share of auctioning from 3% to 10%) and third-party participation (Ministry of Environment, 2020[137]). In order to secure economy-wide momentum for the green transition while preserving industry competitiveness, a clear understanding of private sector needs and a holistic approach to private sector engagement are essential (OECD, 2016[128]). The Fossil-Free Sweden (FFS) Initiative in Sweden offers an interesting benchmark case in this regard (Box 2.1).

Box 2.1. Fossil-Free Sweden (Fossilfritt Sverige): An orchestrator to leverage private sector engagement in building a fossil-free economy

Fossil-Free Sweden (FFS) is a national multi-stakeholder initiative created by the Swedish government in 2015. To date, it has 450 members, including businesses, municipalities, country councils, regions, country boards, civil society, education and research organisations, and industry and trade organisations. Headed by a national co-ordinator, FFS assumes an orchestrator role between the business sector and policies by producing political proposals that are presented to the government ministries and the parliament (*riksdag*).

FFS has three work streams: 1) communicating the identified challenges; 2) building roadmaps for fossil-fuel-free competitiveness; and 3) convening roundtable discussions. Regarding the first work stream, FFS has launched four challenges – transport, solar, internal travel tax and company car – that require concrete climate action, and their aim is to engage actively with their target audience, industry and society in general. The second stream, roadmaps, is the cornerstone of the initiative. As part of FFS, 22 different industries covering the major sectors of the Swedish economy produced their own roadmaps. The roadmaps contain both their commitments and political proposals, and in 2019, FFS issued 54 proposals to help prioritise among the large volume of inputs from industry. In 2021, with the backing of the industries, FFS published a follow-up report reviewing the government initiatives and policies implemented in response to the initially submitted proposals and drawing conclusions on the five most important political decisions and five outstanding challenges (FFS, 2021[138]).

Since the creation of FFS, information sharing among different stakeholder groups has been considered key, and more importantly, the participation of the business sector. There already existed a few voluntary and rather loose industry-led partnerships for climate action in Sweden, but FFS stood out as a state-led initiative to become a facilitator of change rather than a barrier for non-state actors (Nasiritousi and Grimm, 2022[139]). To this end, FFS has adopted key legitimacy-building strategies on the institutional level to focus on the narrative of improving competitiveness. For instance, the Swedish Prime Minister was involved in the initial meetings to increase the initiative's weight as a high-level communication platform.

In the absence of favourable incentives, such as competition, external pressure from reputation and laws, as well as anticipated costs and benefits, the success of this initiative depends on normative factors. In the case of FFS, this hinges on two key factors: 1) the main orchestrator has a non-governmental organisation (NGO) background and also uses language understandable to business, such as business case and competitiveness; 2) the initiative is from government, so the stakeholders know they will capture the attention of relevant ministers. Success is not guaranteed, however, since the FFS has been nominated as one of the top three nominees for Friends of the Earth Sweden's 2021 "greenwash" prize. The NGO says that FFS promotes "business as usual", pointing at unsustainable biomass extraction by the forestry industry as a solution to the climate crisis.

On the positive side, FFS has inspired other decarbonisation initiatives, such as the Leadership Group for Industry Transition, which counts 18 countries and 19 large firms as members, which have committed to national decarbonisation targets, most notably the ambition of achieving net-zero carbon emissions by 2050. In particular, they aim to use the policy window created by COVID-19 to steer economic development onto a more sustainable and inclusive path towards net zero, resisting pressures from carbon-emissions industries to maintain "business as usual" to avoid an increase in costs and job losses (Johnson et al., 2020[140]).

Source: FFS (2021[138]), *Roadmaps for Fossil-Free Competitiveness - Follow-up 2021*, https://fossilfrittsverige.se/wp-content/uploads/2022/01/Roadmaps_follow_up_2021_ENG.pdf; Nasiritousi and Grimm (2022[139]), "Governing toward decarbonization: The legitimacy of national orchestration", https://doi.org/10.1002/eet.1979; Johnson et al. (2020[140]), *Shaping a Sustainable and Low-carbon Recovery that Spurs Industry Transition*, https://view.ckcest.cn/AllFiles/ZKBG/Pages/126/b5e99e6ceca215a50bd7a322d6598b296d448636.pdf.

2.4.3. Leveraging innovation for defence as a response to geopolitical threats

Korea continues to be directly affected by rising geopolitical tensions, in particular by security threats from the Democratic People's Republic of Korea and has thus pledged a record sum of investments for strategic defence purposes. In 2020, Korea had one of the highest government budget allocations for R&D (GBARD) on defence (16.6%), second only to the United States (47.1%) among OECD members (OECD, 2022[24]).

According to the Defense Acquisition Program Administration, the government has set the objective of systematically supporting defence R&D using advancements in innovation as per the Defense Science and Technology Innovation Promotion Act in 2021. More specifically, it is intended to encourage an "open R&D culture" with participation from government research institutes, academia and the private sector, notably also smaller companies (Grevatt, 2021[141]). For this purpose, it seeks to enhance technologies of the Fourth Industrial Revolution that may benefit other sectors through industry linkages. Moreover, this initiative may also set an example for other sectors in terms of inducing deepened co-operation across research institutes, universities and businesses.

2.5. Synthesis

Korea has shown impressive economic and innovation performance. It is among the leading OECD countries in some respects and one of the main laggards in others. The main achievements and challenges discussed in this chapter are listed in Table 2.3.

Table 2.3. Korea's main innovation-related achievements and challenges

Achievements	Challenges
▪ Korea has shown an impressive growth trajectory to high-income status and the innovation frontier. ▪ Strong global leadership in ICT technologies, notably in broadband, 5G and digital government. ▪ Strong economic performance and comparative advantage in manufacturing, notably in advanced products, such as semiconductors and smartphones. ▪ Korea is a leader in spending financial and human resources for R&D. ▪ Korea fares well in investment in green innovation, e.g. in terms of R&D budget and patents for climate mitigation.	▪ Large disparities in industry regarding firm size, between manufacturing and services. ▪ Knowledge-intensive activities are highly concentrated in manufacturing and, in particular, in conglomerates, which holds risks for the overall market. ▪ High productivity gaps across industries and firm size may hinder knowledge diffusion and inclusive growth. ▪ Higher gender equality, e.g. regarding wages and female participation in research, will be critical for inclusive growth and innovation. ▪ Despite FDI regulatory liberalisation efforts, Korea is among the most restrictive OECD countries. ▪ Despite a relatively open migration system, lack of

Achievements	Challenges
	inclusion and working conditions hinder Korea's appeal as a migrant and expat destination. ▪ Korea is expected to have the steepest rise in old-age population by 2050, with structural implications for the economy and innovation system. ▪ Korea's legacy as a developmental state with strong business-state links and weak civil society means carbon emission reduction is sub-par to other leading economies.

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Notes

1. "The concept of national innovation systems rests on the premise that understanding the linkages among the actors involved in innovation is key to improving technology performance. Innovation and technical progress are the result of a complex set of relationships among actors producing, distributing and applying various kinds of knowledge. The innovative performance of a country depends to a large extent on how these actors relate to each other as elements of a collective system of knowledge creation and use as well as the technologies they use. These actors are primarily private enterprises, universities and public research institutes and the people within them. The linkages can take the form of joint research, personnel exchanges, cross-patenting, purchase of equipment and a variety of other channels. There is no single accepted definition of a national system of innovation." (OECD, 1997[150])

2. Strictness Index on dismissal regulation for workers on regular contracts (both individual and collective dismissals). Range of indicator scores: 0-6. Countries with the lowest and highest score are classified as countries with low and high regulatory protection.

3. SMEs are further subdivided into micro enterprises (fewer than 10 employees), small enterprises (10-49 employees), medium-sized enterprises (50-249 employees). Large enterprises employ 250 or more people.

4. Data on Korean firms' use of IoT technologies are not available in the OECD database for comparison.

5. Product innovation is defined as "a new or improved good or service that differs significantly from the firm's previous goods or services and that has been introduced on the market". This includes significant improvements to one or more characteristics or performance specifications, such as quality, technical specifications, user-friendliness or usability. Business process innovation as "a new or improved business process for one or more business functions that differs significantly from the firm's previous business processes and that has been brought into use in the firm". This includes the various functions within a firm, such as the production of goods or services, distribution and logistics, marketing and sales, information and communication systems, and administration and management.

6. Index scale 0-6 from most to least competition-friendly regulation. See OECD (2018[59]).

7. The indicator measures the level of regulations in three service sectors with sub-categories: energy (electricity, gas); transport (rail, air, road, water); and e-communications (fixed, mobile).

8. In Korean, 서비스 R&D 활성화 방안.

9. In Korean, 서비스경제 발전 전략.

10. In Korean, 서비스 R&D 중장기 추진전략 및 투자계획.

11. In Korean, 서비스산업 혁신 전략.

12. In Korean, 국가 필수전략기술 선정 및 육성 보호전략.

13. Artificial intelligence, 5G/6G, advanced biology, semiconductor/display, rechargeable battery, hydrogen, advanced robot manufacturing, quantum technology, aerospace and cybersecurity.

14. In Korean, 국가첨단전략산업 경쟁력 강화 및 보호에 관한 특별조치법.

15. In Korean, 조세특례제한법; the amendment is to take effect as of 2023.

16. Employment in services as a percentage of total employment has increased from 66% in 2013 to 70% in 2019. Source: International Labour Organization, ILOSTAT database.

17. For instance, see Baldwin (2013[151]), De Backer and Yamano (2012[156]) and Cigna, Gunnella and Quaglietti (2022[152]).

18. The GVC Participation Index indicates the level of integration in the vertically fragmented production process, and it distinguishes the "backward participation", i.e. the use of foreign inputs in exports as measured by foreign value-added (FVA) content of gross exports, and "forward participation", i.e. the use of domestic intermediates in third-country exports as measured by domestic value-added (DVA) content of gross exports. The higher the backward participation is, the more a country relies on the sourcing of foreign inputs, and the higher forward participation, the more it supplies intermediate goods and services to other countries, which are then re-exported.

19. GVC income is the value-added contributed by Korean firms (from any industry) in world sales of products from each industry.

20. RCA is an index used for calculating the relative advantage or disadvantage of a certain industry or country. It is calculated as the share of Korea in world GVC income for a given industry divided by the share of Korea in world GVC income. When a country has a revealed comparative advantage for a given product (RCA >1), it is inferred to be a competitive producer and exporter of that product relative to a country producing and exporting that good at or below the world average.

21. For instance, agile trade policies can help firms to switch to alternative suppliers, and innovation policies can promote the emergence of innovative companies to quickly meet the surging demand of certain products.

22. Mitigation strategy is often used interchangeably with the "robustness strategy" (Baldwin and Freeman, 2021[149]; Miroudot, 2020[154]), which by definition is the ability to maintain operations during a crisis (Brandon-Jones et al., 2014[158]). Possible policy scenarios include supplier and buyer diversification and re-shoring or near-shoring of production. Regarding the latter, some claim that further localised production can alleviate the shocks in supply chains and lower uncertainty. However, such argumentation needs to be taken with caution since greater reliance on domestic production not only limits the economy's ability to cushion the shocks but also slows its recovery from GDP losses in the aftermath of the crises (OECD, 2021[79]; Arriola et al., 2020[155]).

23. The Hirschman-Herfindahl Index measures the dispersion of trade value across an exporter's partners. Depending on the level of concentration of a country's trade (export and import) partners, the index can range from 0 ("unconcentrated") to 2 500 ("highly concentrated"). Over 2 500 is considered "highly concentrated", 1 500~2 500 range as "moderately concentrated" and below 1 500 as "unconcentrated".

24. HHI: Korea (954), Japan (928), Netherlands (852), United States (760), China (659), France (545), United Kingdom (525), Italy (490), Germany (431). IIT finds that Korea's trade model places itself at a "high-growth high-return" model where it faces both a high level of volatility and expected return, while most advanced Western European economies and China follow a "low-risk low-return" model. In general, larger economies are better placed for trade diversification. Nevertheless, Japan follows the "high-growth high-return" model since both countries are largely reliant on the Chinese market for their exports (Korea 22.1% of total exports; Japan 19.9%) (KOTRA, 2022[153]).

25. Calculation based on numbers from the Ministry of Education indicate 3.65% of outflows in 2021.

26. Sustainable Development Goal 8: Decent Work and Economic Growth; SDG 9: Industry, Innovation and Infrastructure; SDG 11: Sustainable Cities and Communities.

27. SDG 1: No Poverty, SDG 5: Gender Equality; SDG 10: Reduced Inequality

28. Sectors include forestry, waste, domestic aviation, transport, buildings, industry and power.

29. Explicit carbon price is about EUR 10 per tonne for most industries. In the electricity generation sector, the price goes up to USD 31.7 per tonne due to excise tax.

30. Sectors that meet one of the following conditions may receive 100% of their allowances for free during a certain phase: 1) sectors whose production cost rate (ratio of total allowance cost among total value-added production, specifically defined in the Presidential Decree to ETS Act) is 30% or more; 2) sectors whose trade intensity level (specifically defined in the Presidential Decree to ETS Act) is 5% or more; or 3) sectors whose production cost rate is 5% or more and at the same time has a trade intensity level of 10% or more.

31. Carbon leakage refers to the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with laxer emission constraints. This could lead to an increase in their total emissions. The risk of carbon leakage may be higher in certain energy-intensive industries.

32. Hyundai Motors, SK, Lotte, POSCO, Hanwha, Hyundai Heavy Industries, GS, Doosan, Hyosung, Kolon.

33. According to Jung et al. (2021[136]), carbon productivity is measured as a firm-level revenue created per unit of carbon emission. It is calculated as CPi,t=Revenuei.t/Emissioni,t. where CPi,t is the carbon productivity of firm i in year t, Revenuei,t is the annual sales generated by firm i in year t, and Emissioni,t is the level of GHGs emitted by firm i in year t. For clarity, all of the carbon productivity values are multiplied by 1 million. For the top three industries with the highest emission levels – basic metals, chemicals and chemical products and other non-metallic mineral products – the figures increased, respectively, from 7.9 to 10.4 (before ETS and ETS Phase 2), from 4.7 to 8.8, and from 1.8 to 6.3.

3 Business sector research and development and innovation in Korea

This chapter reviews the business sector's research and development (R&D) and innovation performance in Korea, drawing on extensive qualitative and quantitative analysis, including a benchmarking of the country's technology specialisation in digital and green technologies. It highlights the challenges posed by the polarisation of business innovation performance across different sectors and between larger and smaller firms. Finally, it discusses the recent policy reforms taken to address these imbalances as well as the need for adjusting the policy mix for business innovation to ensure Korea's business sector can seize the opportunities of the digital and green transitions.

Korea has built a very innovative and dynamic business sector, which has been the engine of economic growth and prosperity. However, the success of the Korean business sector has been overshadowed by acute discrepancies across firms and industries: 1) an innovation divide between large firms and small and medium-sized enterprises (SMEs); 2) the productivity gap between information and communication technology (ICT) and non-ICT industry; and 3) a disparity in innovation investments between manufacturing and services.

The chapter begins with a general diagnosis of business sector R&D and innovation in Korea that is followed by a series of policy recommendations.

First, the exceptionally high concentration in R&D spending on the few largest companies in Korea sheds light on the growing discrepancy between large companies and SMEs. A significant gap in R&D investment has resulted in an innovation divide between larger and smaller firms and a decline in the ability of SMEs to absorb new technologies and further their digitalisation. The strong commitment and support for SMEs by the government is encouraging, and there is evidence of a maturing start-up ecosystem, especially around Seoul. The government should sustain its support for SMEs and start-ups with more streamlined and impact-oriented programmes. In particular, the government could strengthen support for the global connectivity of SMEs and start-ups to help scale up and reach new markets.

Second, the ICT industry in Korea has achieved remarkable growth and is now a global leader. However, there is also a widening discrepancy between ICT and non-ICT industry in various aspects ranging from R&D investment to productivity. In fact, the productivity of the non-ICT manufacturing industry is only half that of the ICT manufacturing sector. The government has long strived to support the diversification of its industrial landscape and reduce its reliance on the ICT industry. In this regard, the emergence of the biotech industry is impressive. The share of Korean biotechnology patents has increased significantly, and so has the number of biotech start-ups. The growth of the biotech industry is especially noteworthy in that the public R&D investment paved the way for its successful take-off. The government should continue to foster new and emerging technology-based firms and industries by promoting collaborative R&D and innovation activity across different firms and with academia.

Finally, the large discrepancy in productivity and investment between the manufacturing and the service industry persists despite active government support. Meanwhile, knowledge-based services, notably the software industry, offer the potential for higher value-added and balanced growth in the Korean economy. The government should enhance the role of services by developing a dedicated innovation strategy and addressing remaining regulatory barriers. In particular, the government should support the expansion of "servicification", which represents the phenomenon whereby services are increasingly embedded in manufacturing products.

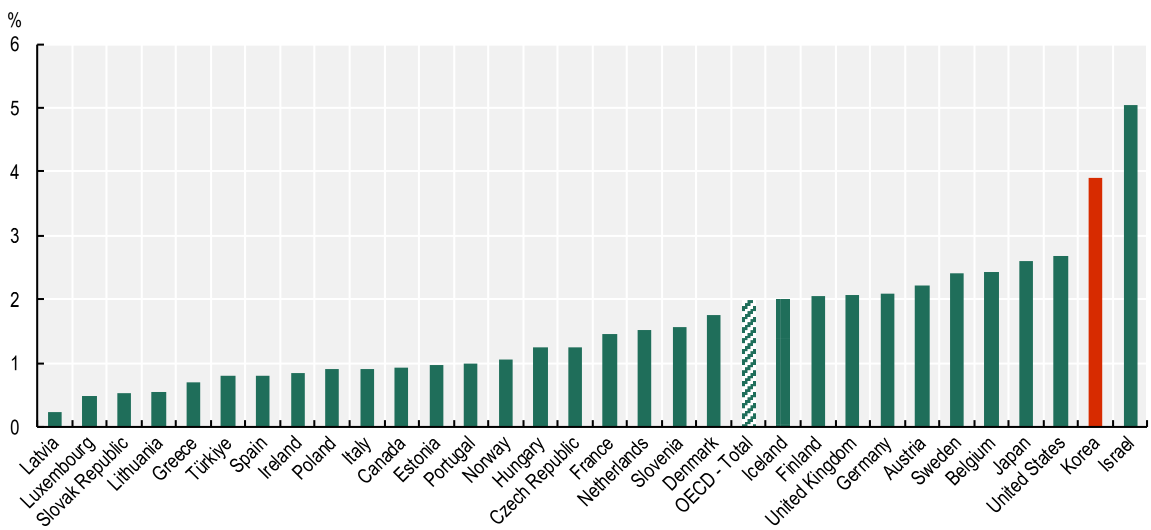
3.1. A general assessment of business innovation in Korea

This section describes Korean business research and development (R&D) and innovation performance and overall strengths based on different indicators. It highlights some of the critical imbalances in business sector innovation performance, notably the dominance of large manufacturing-based R&D, that prevent Korea from harnessing its full productivity potential through innovation in services and by smaller firms. Recognising the positive contributions of recent policies to address the imbalances in business innovation performance, the section advocates for well-designed policy support for *emerging technologies* to help Korea's business sector seize the opportunities from the digital and green transitions, not only in manufacturing but also in services.

3.1.1. Korean business R&D has grown rapidly and leads globally

Business sector R&D in Korea more than doubled from KRW 32.8 trillion (Korean won) in 2010 to KRW 68.8 trillion in 2019 (OECD, 2021[1]). Moreover, business enterprise expenditures on R&D (BERD) amounted to 3.9% of gross domestic product (GDP) in Korea in 2021, which is more than double the OECD average and the second-highest business R&D intensity among all OECD countries, behind Israel (Figure 3.1) (OECD, 2023[2]). In terms of business R&D expenditure, 60 of the global top 2 500 firms are Korean, including Samsung Electronics and other chaebols. In 2020, Korea hosted the highest number of R&D players after the United States (779 firms), the People's Republic of China (hereafter "China") (597), Japan (293), Germany (124), the United Kingdom (105), Chinese Taipei (86) and France (66) (European Commission, 2022[3]).

Figure 3.1. Business enterprise expenditures on R&D as a percentage of GDP, OECD countries, 2021

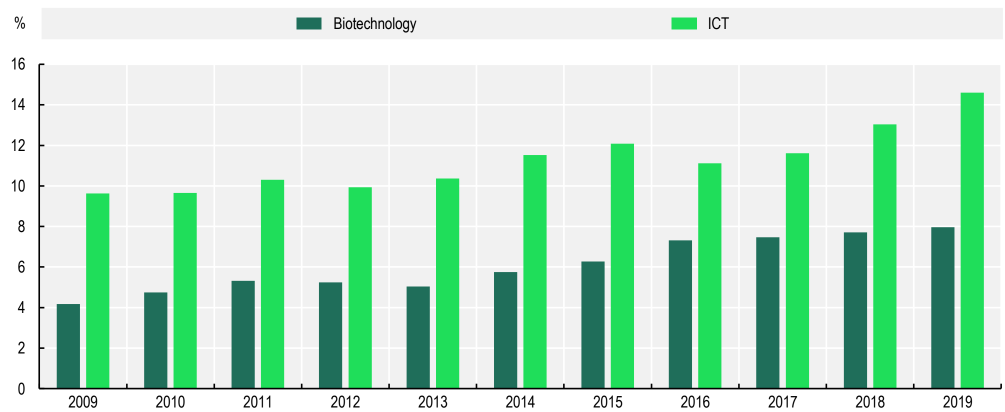


Source: OECD (2023[4]), "Main Science and Technology Indicators", *OECD Science, Technology and R&D Statistics* (database), https://doi.org/10.1787/data-00182-en (accessed on 8 June 2023).

Outcomes of R&D activities can be measured through intellectual property (IP) production and, in particular, patents, which are mainly applied for by the business sector. The number of Korean patents filed under the PCT (Patent Cooperation Treaty) increased from 8 731 (5.6% of the world total) in 2009 to 17 333 (6.8% of the world total) in 2018 (OECD, 2023[2]). Moreover, Korea's patent performance has improved not only in absolute but also in relative terms. The country's patent share within the OECD has increased in high-tech industries, such as ICT and biotechnology (Figure 3.2). As of 2017, Korea had the second-highest number of ICT patent filings among all OECD countries, behind Japan, and the third-highest number of biotechnology patent filings, behind the United States and Japan. Korea's patent filings per unit of GDP have been higher than in the United States and Japan in both high-tech sectors (Hemmert, 2020[4]).

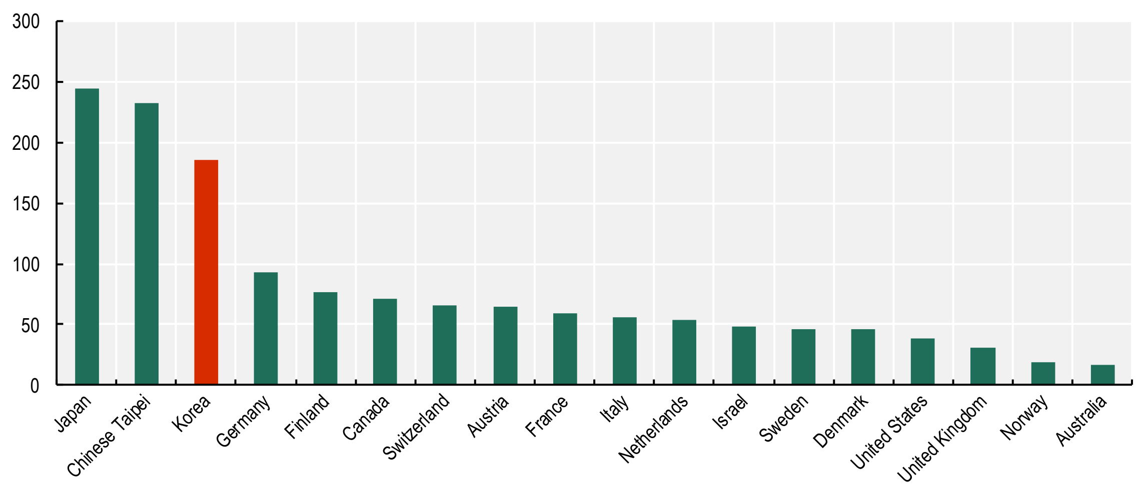
Individual Korean companies have also increased their IP positions in impressive ways. As of 2020, Samsung Electronics and LG Corporation have ranked second and third in the number of US utility patents among all companies worldwide (Harrity, 2021[5]). Moreover, strong R&D investment combined with high patent filing has advanced Korea over other economies in terms of patenting performance to R&D expenditure. Korea has placed third after Japan and Chinese Taipei (Figure 3.3).

Figure 3.2. Korea's share in OECD ICT and biotech PCT patents, 2009-19



Note: Patent data are based on the inventor's residence and priority year.
Source: Authors' calculations based on OECD STI Micro-data Lab: Intellectual Property Database, http://oe.cd/ipstats, accessed on 9 June 2023).

Figure 3.3. Number of IP5 patents family per USD Billion of GERD, selection of economies, 2019



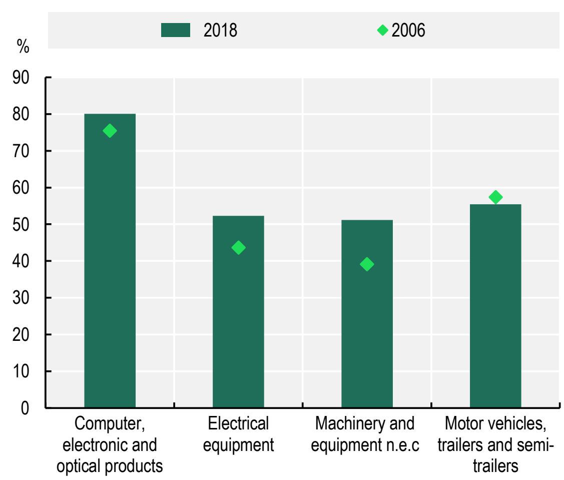
Note: Patent data are based on the inventor's residence and priority year. IP5 patent families refer to patents filed in at least two IP offices among five major patent offices in China, Europe, Japan, Korea and the United States.
Source: Authors' calculations based on OECD*, STI Micro-data Lab: Intellectual Property Database*, http://oe.cd/ipstats (accessed on 9 June 2023) and (OECD, 2023[2]), "Main Science and Technology Indicators", *OECD Science, Technology and R&D Statistics (database)*, https://doi.org/10.1787/data-00182-en (accessed on 8 June 2023).

3.1.2. Korea is advancing toward knowledge-intensive industry with increased global market share in high-tech products

Innovation performance can be associated with the ratio of domestic value added to gross exports in high-tech industries. When Korea industrialised, companies in knowledge-intensive industries initially focused on downstream activities, such as the final assembly of electronic products and automobiles. As a result, the value added within Korea represented a relatively low share of industry output and exports. However, this ratio has significantly increased across major knowledge-intensive industries (Figure 3.4). As a result of the technological upgrading of Korean firms and foreign suppliers' direct investment in Korea, value chains in knowledge-intensive manufacturing industries, which play a leading role in Korean exports, appear to have been localised to a high degree.

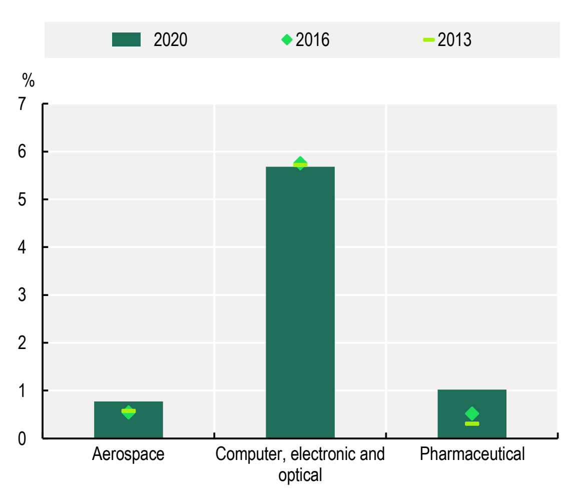
Business innovation performance can also be observed later in the innovation process through companies' competitive performance, which can strongly reflect their innovation performance in high-tech industries (Figure 3.5). The world export market share of Korean companies in the computer, electronic and optical industry is above 5% and third-highest among all countries, behind China and the United States. Korean companies still have a small but growing share of the global export market in the pharmaceutical and aerospace industries.

Figure 3.4. Korea's share of domestic value added embodied in foreign final demand, 2006 and 2018 for a selection of industrial sectors



Note: Computer, electronics and optical products correspond to Isic D26, Electrical equipment D27, Machinery and equipment n.e.c D28 and Motor vehicles, trailers and semi-trailers D29
Source: OECD (2023[6]), "Trade in value added", *OECD Statistics on Trade in Value Added* (database), https://doi.org/10.1787/data-00648-en, (accessed on 9 June 2023).

Figure 3.5. World export market share of Korean firms in high-tech industries



Source: OECD (2023[7]), "Main Science and Technology Indicators", *OECD Science, Technology and R&D Statistics* (database), https://doi.org/10.1787/data-00182-en, August 2022.

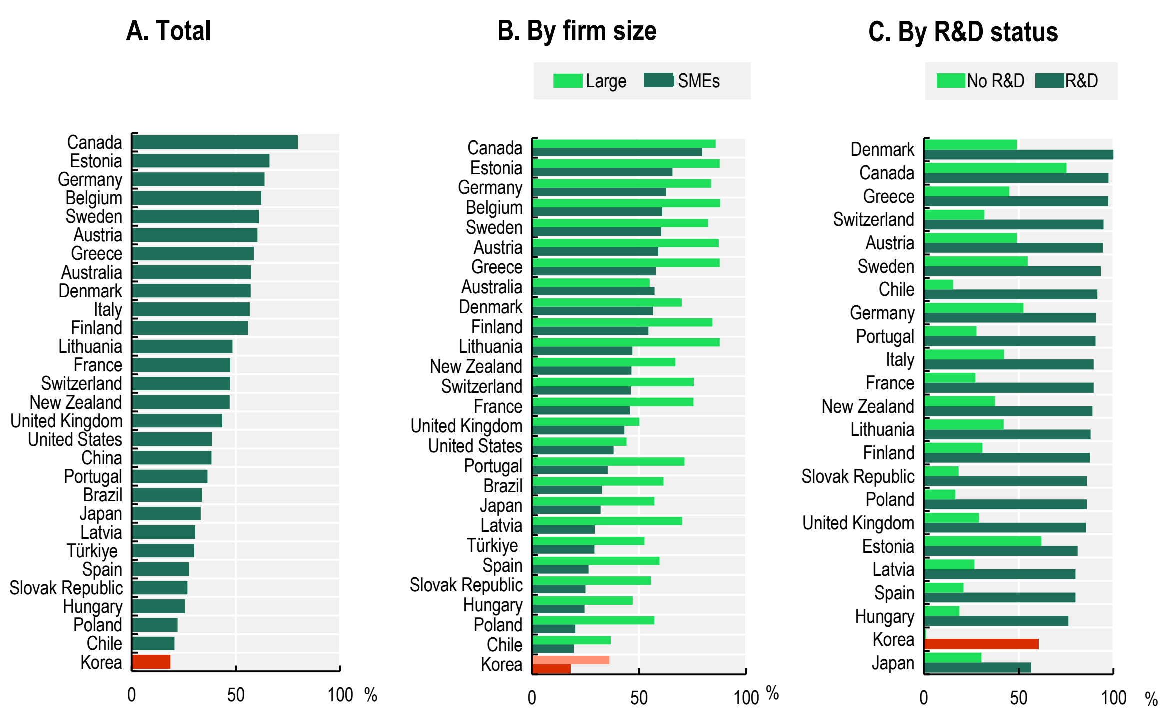
3.1.3. Despite outstanding progress in business innovation, Korean firms' innovation performance still has room for improvement

Overall, the Korean business sector's innovation performance is strong and improving with impressive scale and speed when measured by IP production, export competitiveness in high-tech industries and domestic value added in knowledge-intensive industries. In particular, Korean firms' performance is strong in the ICT sector in many measures. However, somewhat different pictures emerge when assessing the innovation performance activities of Korean firms from different angles.

First, Korea's total ratio of innovating firms is the lowest among all OECD countries, and the low ratio of innovating firms consistently holds across firm size and R&D status (Figure 3.6). Furthermore, it is second-lowest in product innovation and the lowest in business process innovation (OECD, 2020[8]). Meanwhile, the most recent Korean Innovation Survey (KIS) on innovation activities by Korean manufacturing firms from 2017 to 2019 reveals several features of firm innovation activities in a more detailed manner. Overall, 14.2% of Korean manufacturing firms introduced a new product or service (product innovation); 17.8% innovated in processes, organisationally, or in marketing (business process innovation); and 20.6% innovated in at least one of the two categories (Figure 3.7). Adjusted values for Korea calculated for direct comparison with Community Innovation Survey (CIS) data are 23.8% for product innovation and 28.3% for business process innovation – thereby closer to, but still below, the EU average (STEPI, 2021[9]). Caution should be used when translating the results of the innovation surveys, however, due to cultural differences and different industrial landscapes across countries.

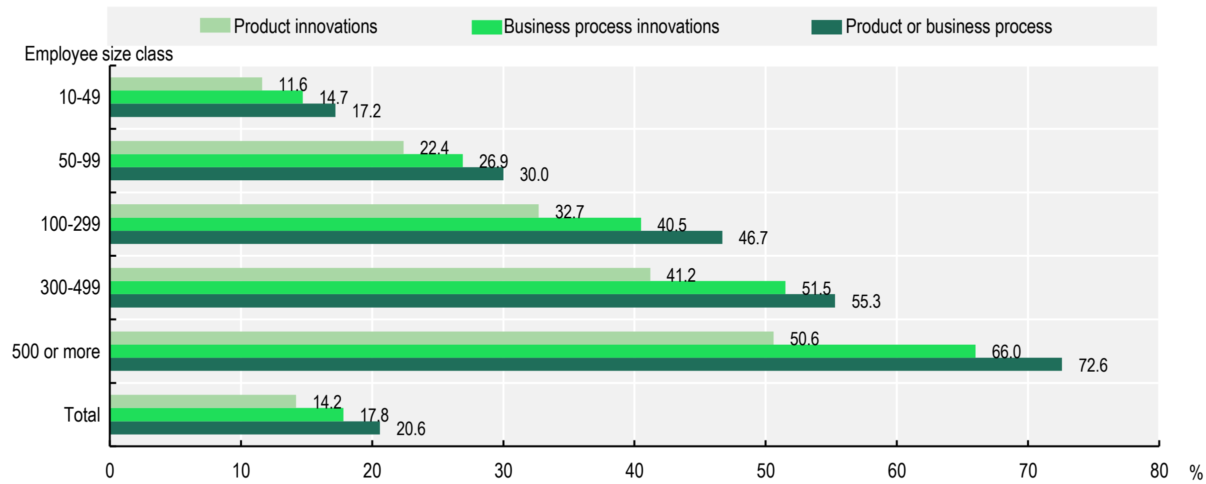
Figure 3.6. Innovative firms in Korea and selected countries, 2016-18

As a percentage of total firms (within the scope of national innovation surveys) within each group



Note: Innovative firms are those reporting at least one product or business process innovation in the reference period (2016 18).
Source: OECD calculations, based on the 2021 OECD Survey of Business Innovation Statistics and the Eurostat's Community Innovation Survey (CIS-2018), https://www.oecd.org/sti/inno-stats.htm, April 2022.

Figure 3.7. Share of innovating Korean manufacturing firms, 2017-19



Source: STEPI (2021[10]), *Report on the Korean Innovation Survey 2020: Manufacturing Sector 2019*, https://www.stepi.re.kr/kis/service/sub03_report.do.

Second, most Korean firms significantly rely on in-house R&D when innovating. Some 39.4% of Korean manufacturing firms conduct in-house R&D. In comparison, 5.6% engage in collaborative R&D, and 1.6% rely on out-contracted R&D. Among large firms with 500 or more employees, 94.3% conduct in-house R&D. In comparison, only 32.9% and 11.8% rely on collaborative and out-contracted R&D, respectively (STEPI, 2021[10]). The high ratio of in-house R&D in the Korean manufacturing industry is associated with a high level of vertical integration. In comparison, 12.2% of all manufacturing firms in the EU27 have contracted out R&D. Among medium-sized and large companies, the propensity to out-contract R&D exceeds 30% in many EU countries (Eurostat, 2021[11]). On top of R&D activities, Korean firms rely to a great extent on internal information sources when innovating. Among the surveyed manufacturing firms, 83.0% use company-internal sources of innovation. The second and third most frequent information sources are external private firms and universities and higher education institutions, which have been used by 27.7% and 19.7% of the firms, respectively. The statistics above imply that Korean business still has room for improvement regarding promoting open innovation, which espouses sourcing ideas from external and internal sources.

Third, most innovation activities by Korean firms are focused on R&D. Some 80.8% of their innovation expenses fall to in-house R&D, followed by 13.2% for in-house non-R&D expenses, 4.2% for collaborative R&D expenses and 1.3% for out-contracted R&D expenses. In contrast, the innovation expenses of innovating firms in most of Europe are less concentrated on R&D expenses in general and in-house R&D expenses in particular (Eurostat, 2021[11]).

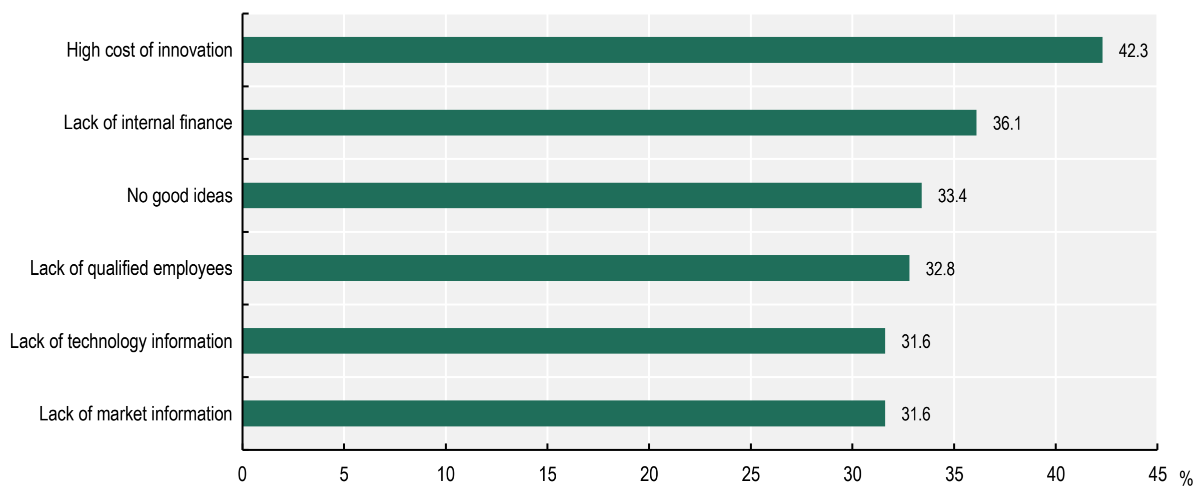
Finally, Korean manufacturing firms mostly focus on incremental innovation. While 85.9% of the firms surveyed in the KIS 2020 worked on improving existing goods or services, only 39.8% targeted introducing new goods or services. This incremental innovation focus can be broadly observed across different enterprise size classes and industries (STEPI, 2021[10]). Meanwhile, it is worth noting that the Korean government is encouraging disruptive innovation and more innovative R&D across industry, as illustrated by the recently launched Alchemist Project that aims to develop technologies to transform industry.

3.1.4. Financial difficulties and a lack of qualified labour hinder Korean firms’ innovation

According to KIS 2020, the innovation barriers most frequently recognised as significant by Korean firms have been the high cost of innovation (42.3%), followed by a lack of internal finance (36.1%) and no good ideas (33.4%) (Figure 3.8). A lack of qualified employees and technology and market information also constitute important innovation barriers for Korean manufacturing firms. Overall, barriers related to financial difficulties and companies' capabilities are most frequent. In contrast, market-related barriers (e.g. uncertainty about market demand) and necessity-related barriers (e.g. no need for additional innovation) are regarded not as hindering as financial difficulties and firms' capabilities (STEPI, 2021[10]). Similar observations have been made for service firms, which play a lesser role in business innovation in Korea than manufacturing firms. The innovation barriers reported most frequently as significant by Korean service companies in the years 2015-17 have been a lack of internal finance, difficulties with obtaining financial support from the government and the high cost of innovation (STEPI, 2019[12]). Service companies appear to rely to a relatively high degree on government support for innovation, as they have identified difficulties with obtaining such support as one of the most frequently significant innovation barriers.

Figure 3.8. Innovation barriers for Korean manufacturing firms, 2017-19

Percentage of firms that perceived barriers as high



Source: (STEPI, 2021[10]), *Report on the Korean Innovation Survey 2020: Manufacturing Sector 2019*, https://www.stepi.re.kr/kis/service/sub03_report.do.

The finance- and capability-related innovation barriers in Korea are more important for smaller than for larger firms. However, they are highly relevant even for many large firms. While 46.0% of small firms with 10-49 employees perceive the high cost of innovation as an important innovation barrier, the proportion of large firms with 500 or more employees that share this perception is 40.3%. The size-related difference is greater regarding the lack of internal finance, which is perceived by 38.9% of small firms and 15.8% of all large firms as a significant innovation barrier (STEPI, 2021[10]). In other words, while small Korean manufacturing firms often do not innovate due to high cost or lack of finance, large firms may have more internal financial resources but also do not innovate due to high cost. Overall, while most Korean firms feel a need to innovate, they are frequently hindered from doing so due to a lack of resources and capabilities, including finance, qualified staff, ideas and technology- and market-related information.

3.1.5. Internationalisation of business R&D and innovation is still relatively low

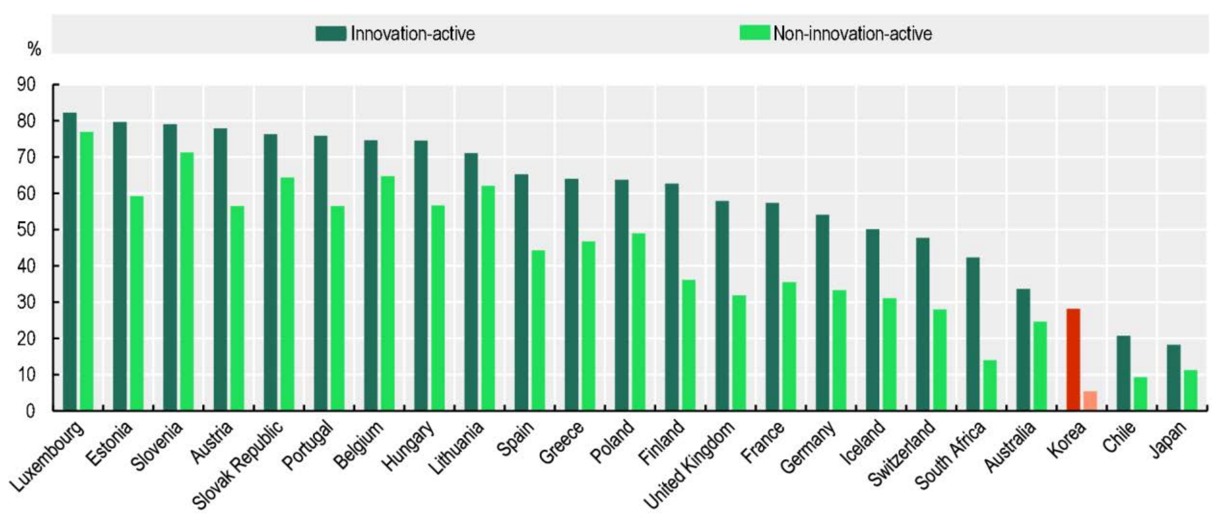
Business R&D in Korea is dominated largely by domestic companies. The R&D expenditures by foreign-owned companies in the manufacturing sector amounted to only 3.9% of all manufacturing sector R&D in 2018 (KISTEP, 2019[13]). In the meantime, the number of non-Korean companies with R&D activities in

Korea increased from 60 in 1999 to 375 in 2014 (Hemmert, 2018[14]), indicating an increasing interest by foreign multinationals to conduct R&D in Korea.

The degree of global integration of Korean business innovation is also relatively low among developed countries, yet increasing, partly due to the expansion of Korean conglomerates and policy initiatives such as the "Buy R&D" fund (KRW 100 billion), which supports technology adoption, the promotion of global mergers and acquisitions (M&As) and international joint R&D projects. Regarding inward global integration, R&D spending by foreign multinationals in Korea has rapidly increased from a very low base (Figure 3.9). Many foreign multinationals are active in upstream manufacturing industries, such as chemicals, high-tech materials and automotive parts and components (Hemmert, 2020[4]). Meanwhile, in terms of outward global R&D integration, some Korean conglomerates have established overseas R&D labs to support the customisation of their products or to acquire new technologies that are leveraged in their global new product development (Hemmert, 2018[14]). Recent OECD business innovation indicators also confirm the relatively weak global market integration of Korean businesses (OECD, 2020[8]). For example, Korean business shows low shares of firms operating in global markets regardless of whether they are innovative.

Figure 3.9. Firms operating in foreign markets in Korea and selected countries, by innovation-active status, 2016-18

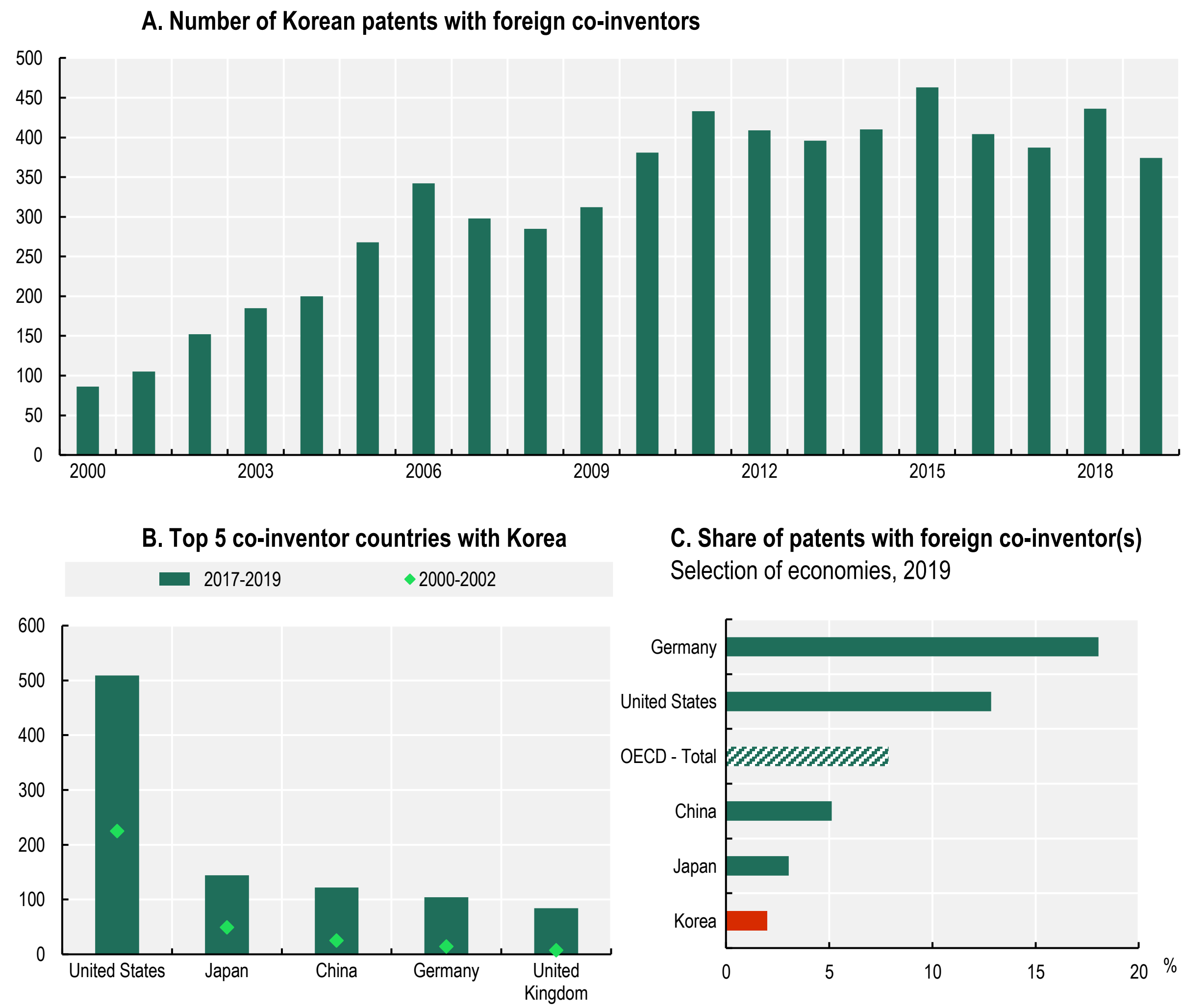
As a percentage of innovation-active firms and non-innovation-active firms, respectively



Note: Innovative firms are those reporting at least one product or business process innovation in the reference period (2016 18).
Source: OECD based on the 2021 OECD Survey of Business Innovation Statistics and Eurostat (Eurostat, 2021[11]), *Community Innovation Survey (CIS 2018)*, https://www.oecd.org/sti/inno-stats.htm, April 2022.

The degree of R&D globalisation can also be observed through co-patenting activities. The number of patents jointly published by Korean and foreign applicants greatly increased in the late 2000s and early 2010s (Figure 3.10 Panel A). Most Korean co-patenting has occurred with partners in the United States, followed by Japan, China, Germany, India and the Russian Federation (hereafter, "Russia") (Figure 3.10, Panel B). Overall, while international co-patenting by Korean firms has increased since the turn of the millennium, the recent decrease suggests that the scale of the firms' global R&D activities may have levelled off. Moreover, Figure 3.10 (Panel C) reveals that Korean international co-operation in patenting with countries abroad is much behind the OECD average.

Figure 3.10. Korean co-patenting, 2000-17



Note: In the last few years, data may be partly due to time lags between the application and publication dates (generally taking one and a half years). Counting patents with multiple inventors/applicants: the indicators presented here are based on simple counts.
Source: OECD (2022[15]), *STI Micro-data Lab: Intellectual Property Database*, http://oe.cd/ipstats, May 2022.

3.1.6. Korean technology is highly specialised in ICTs but less so in other emerging technologies

This section provides a snapshot of technology specialisation in the Korean business sector, emphasising selected technology fields instrumental to the digital and green transitions. Table 3.1 shows Korea's revealed technology advantage (RTA[1]), measured as an index greater than 1, against the world average across the World Intellectual Property Organization classification of 35 technologies.[2] Korea's specialisation in ICT or semiconductors remains robust, while it has reinforced its specialisation in certain domains such as biotechnology. Although Korea's technology specialisation remains concentrated in a few selected technology domains, its RTA has become more diversified as its economy has advanced, adding more complexity to its industrial landscape. Table 3.2 illustrates the RTA distribution of 35 technology domains across selected economies. In domains where Korea has high indices, including semiconductors and nanotechnology, Chinese Taipei and China demonstrate similar propensity. On the contrary, Germany and Japan appear to have greater RTA in mechanical areas, whereas Korea shows relatively low indices. While Korea has increased its specialisation in chemical, biotechnology and pharmaceutical technologies (Panel B), it is still below that of the United States and Germany.

Table 3.1. Technology specialisation (RTA), IP5 patent families in Korea, 2004-18

Field of technology	2004-08	2009-13	2014-18
Electrical machinery, apparatus, energy	1.2	1.2	1.2
Audio-visual technology	1.8	1.7	1.7
Telecommunications	2.1	1.6	1.2
Digital communication	1.6	1.5	1.2
Basic communication processes	1.5	1.2	1.2
Computer technology	1.3	1.5	1.4
IT methods for management	0.9	1.1	0.9
Semiconductors	2.3	2.1	2.1
Optics	1.5	1.2	1.2
Measurement	0.5	0.7	0.7
Analysis of biological materials	0.5	0.7	0.7
Control	0.6	0.7	0.6
Medical technology	0.3	0.5	0.6
Organic fine chemistry	0.4	0.6	1.1
Biotechnology	0.5	0.7	0.7
Pharmaceuticals	0.3	0.5	0.6
Macromolecular chemistry, polymers	0.6	0.8	1.1
Food chemistry	0.4	0.5	0.8
Basic materials chemistry	0.5	0.6	0.8
Materials, metallurgy	0.6	0.8	0.9
Surface technology, coating	0.7	1.0	0.9
Micro-structural and nano-technology	1.9	1.7	0.8
Chemical engineering	0.6	0.7	0.7
Environmental technology	0.5	0.6	0.8
Handling	0.4	0.4	0.4
Machine tools	0.3	0.4	0.4
Engines, pumps, turbines	0.4	0.4	0.6
Textile and paper machines	0.6	0.4	0.3
Other special machines	0.4	0.5	0.5
Thermal processes and apparatus	1.3	0.9	1.0
Mechanical elements	0.3	0.5	0.6
Transport	0.4	0.7	0.8
Furniture, games	0.8	0.7	0.8
Other consumer goods	1.5	1.2	1.3
Civil engineering	0.4	0.4	0.4

Note: IP5 patent families refer to patents filed in at least two IP offices among five major patent offices of China, Europe, Japan, Korea and the United States. These tables show red gradients as RTAs increase above 1.0 (RTA>1.0) and blue gradients as RTAs decrease below 1.0 (RTA<1.0)

Source: Authors' calculations based on OECD (2022[15]), *STI Micro-data Lab: Intellectual Property Database*, http://oe.cd/ipstats, May 2022.

Table 3.2. Technology specialisation (RTA), IP5 patent families in Korea and selected economies

Field of technology	Korea	Germany	Japan	United States	China	Chinese Taipei
Electrical machinery, apparatus, energy	1.2	1.1	1.3	0.7	1.0	1.2
Audio-visual technology	1.7	0.4	1.2	0.6	1.7	1.9
Telecommunications	1.2	0.5	1.1	0.9	1.4	1.3
Digital communication	1.2	0.4	0.5	1.2	2.4	0.8
Basic communication processes	1.2	0.6	1.0	1.0	0.9	1.9
Computer technology	1.4	0.4	0.8	1.1	1.6	1.5

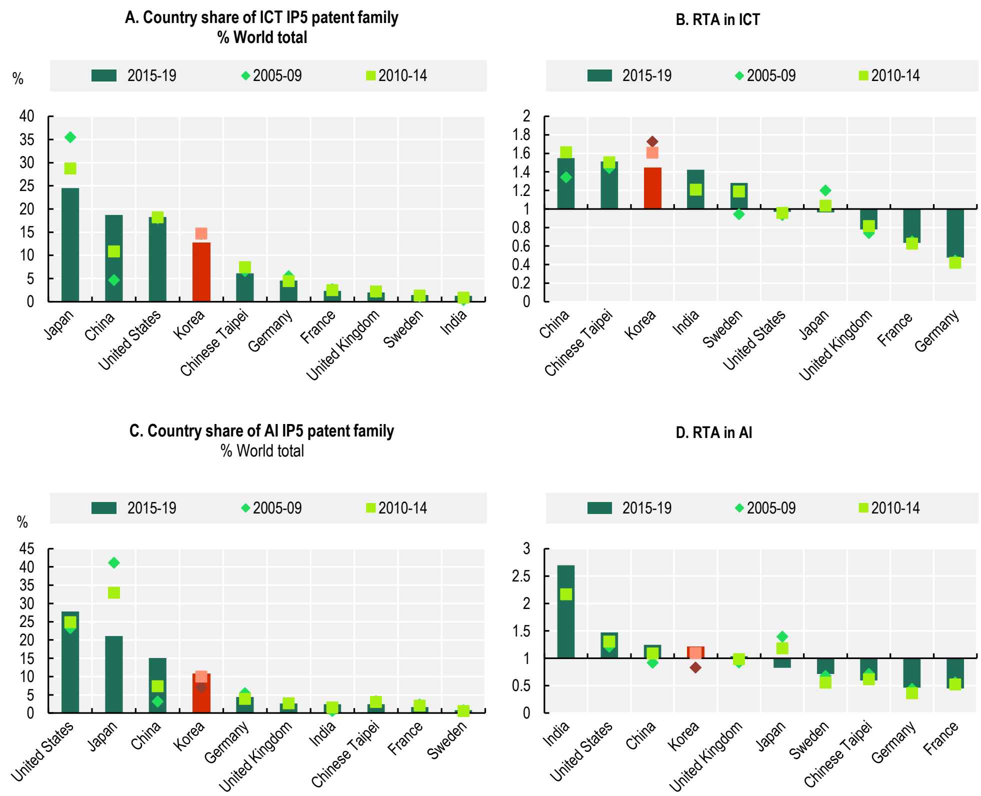
Field of technology	Korea	Germany	Japan	United States	China	Chinese Taipei
IT methods for management	0.9	0.4	0.8	1.4	1.3	0.7
Semiconductors	2.1	0.4	1.2	0.6	1.2	3.0
Optics	1.2	0.4	1.7	0.5	1.5	1.7
Measurement	0.7	1.4	1.0	1.0	0.8	0.8
Analysis of biological materials	0.7	0.9	0.6	1.5	0.5	0.6
Control	0.6	1.1	1.1	1.1	0.9	0.8
Medical technology	0.6	0.9	0.7	1.6	0.5	0.6
Organic fine chemistry	1.1	1.2	0.6	1.2	1.0	0.4
Biotechnology	0.7	0.7	0.5	1.9	0.8	0.5
Pharmaceuticals	0.6	0.5	0.4	2.0	0.8	0.6
Macromolecular chemistry, polymers	1.1	0.9	1.5	0.8	0.6	0.5
Food chemistry	0.8	0.6	0.7	1.2	0.6	0.4
Basic materials chemistry	0.8	1.0	1.1	1.1	0.6	0.4
Materials, metallurgy	0.9	1.1	1.4	0.8	0.8	0.4
Surface technology, coating	0.9	1.0	1.4	0.9	0.7	0.8
Micro-structural and nano-technology	0.8	1.4	0.6	1.0	1.1	2.1
Chemical engineering	0.7	1.4	0.7	1.1	0.8	0.5
Environmental technology	0.8	1.5	0.9	1.0	0.7	0.4
Handling	0.4	1.5	1.1	0.8	0.6	0.5
Machine tools	0.4	2.0	1.1	0.8	0.6	1.0
Engines, pumps, turbines	0.6	1.6	1.0	1.3	0.3	0.3
Textile and paper machines	0.3	1.0	2.0	0.6	0.4	0.4
Other special machines	0.5	1.6	0.9	1.0	0.5	0.6
Thermal processes and apparatus	1.0	1.2	1.1	0.7	0.8	0.6
Mechanical elements	0.6	2.1	1.0	0.9	0.5	0.5
Transport	0.8	1.8	1.1	1.0	0.4	0.3
Furniture, games	0.8	1.2	0.7	0.9	1.0	1.2
Other consumer goods	1.3	1.2	0.7	0.8	1.0	0.7
Civil engineering	0.4	1.6	0.4	1.3	0.6	0.5

Note: IP5 patent families refer to patents filed in at least two IP offices among five major patent offices of China, Europe, Japan, Korea and the United States. These tables show red gradients as RTAs increase above 1.0 (RTA>1.0) and blue gradients as RTAs decrease below 1.0 (RTA<1.0)
Source: Authors' calculations based on OECD (2022[15]), *STI Micro-data Lab: Intellectual Property Database*, http://oe.cd/ipstats, May 2022.

While Korea has accumulated patents in the fields of ICT and artificial intelligence (AI) and holds high shares compared to the world total (13.8% in ICT and 9.8% in AI) (Figure 3.11, Panel A), its specialisation differs in each field. For ICT, it shows greater value of RTA indices exceeding 1 after China and Chinese Taipei, whereas, for AI, Korea's RTA is slightly above 1, indicating a little positive specialisation (Figure 3.11, Panel B). Thus, despite Korea's relative strength in ICT in general, the country may do well to devote considerable efforts to specialise in AI, an emerging and enabling technology for Korea's digital transformation. In AI, India, Israel, the United States and China have a higher RTA.

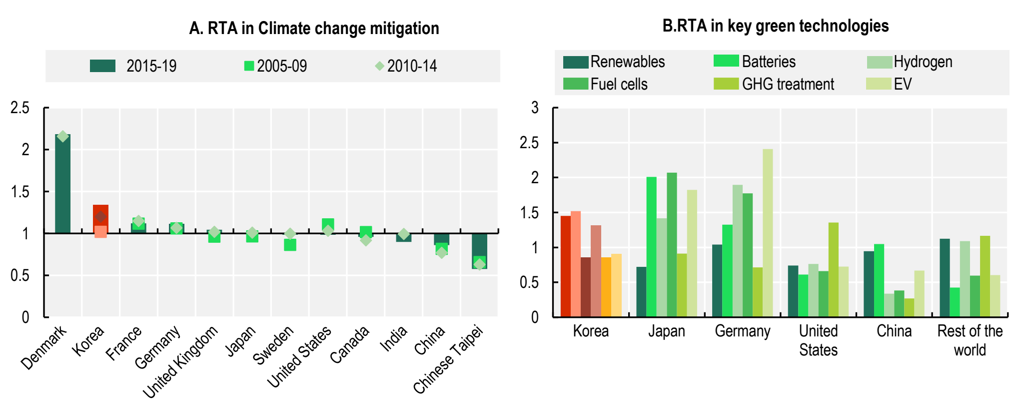
In contrast to its performance in ICTs, Korea's specialisation in environmental technologies is below the world average, with an RTA below 1. However, in terms of climate change mitigation/adaptation technology, in particular among environmental technologies, Korea ranks second after Denmark (Figure 3.12, Panel A). Among the sub-categories in climate change mitigation or adaptation technologies, Korea has the highest RTA in renewables (Figure 3.12, Panel B) among comparable advanced economies. Korea's RTA in batteries and fuel cells also exceeds 1, while hydrogen, treatment of greenhouse gas (GHG) and electric vehicles are below 1. Based on company-level data, Korean firms such as LG Chem and LG Electronics have emerged as global leaders in patenting and trademarks on climate change mitigation/adaptation technologies (Figure 3.13).

Figure 3.11. Country patent share and relative specialisation in ICT and AI patent families, for a selection of economies



Note: IP5 patent families refer to patents filed in at least two IP offices among five major patent offices of China, Europe, Japan, Korea and the United States.
Source: OECD, *STI Micro-data Lab: Intellectual Property Database*, http://oe.cd/ipstats, June 2023

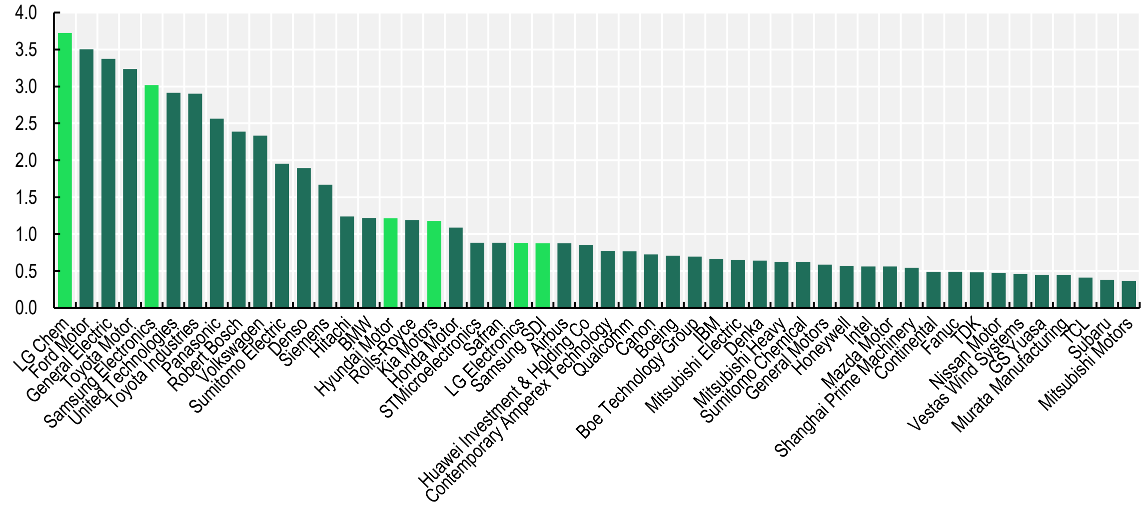
Figure 3.12. Technology specialisation (RTA) in climate change mitigation for a selection of economies



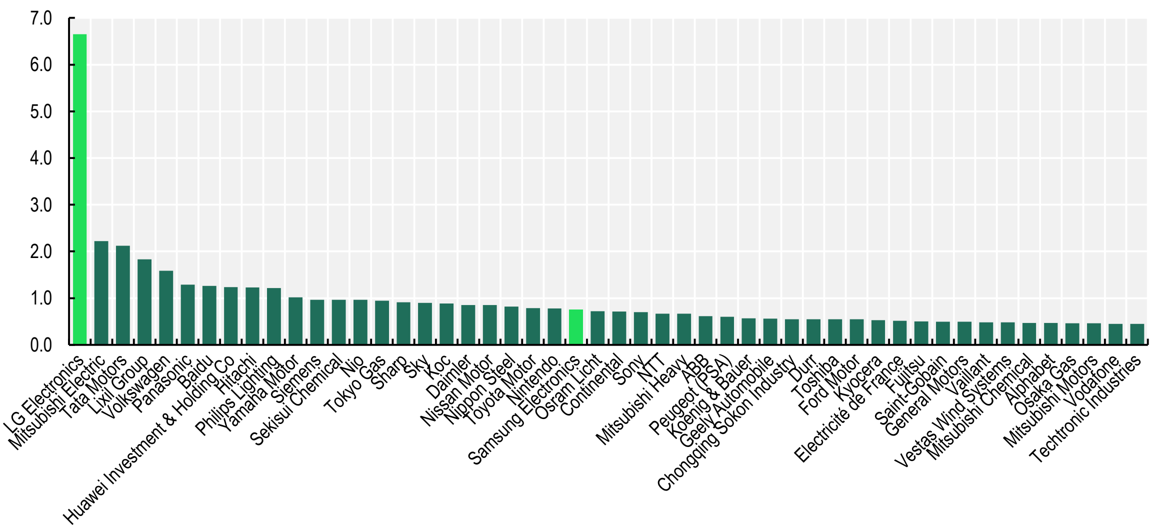
Note For Panel A: IP5 patent families refer to patents filed in at least two IP offices among five major patent offices of China, Europe, Japan, Korea and the United States.
Source: Authors' calculations based on *STI Micro-data Lab: Intellectual Property Database*, http://oe.cd/ipstats, June 2023 and on OECD (2023), "Patents in environment-related technologies: Technology development by inventor country", *OECD Environment Statistics* (database), https://stats.oecd.org/Index.aspx?DataSetCode=PAT_DEV (accessed on 20 June 2023).

Figure 3.13. Top 50 patenting or trademarking companies in climate change mitigation and adaptation, 2016-18

A. Top 50 patenting companies



B. Top 50 trademarking companies



Note: Bars in red are Korean firms. IP5 patent families and trademarks at the EUIPO, JPO and USPTO. Data relate to the share of the patents (respectively trademarks) related to climate change mitigation and adaptation owned by companies in total patents (respectively trademarks) in that domain owned by the top 2 000 corporate R&D sample in 2016-18.
Source: European Commission et al., (2021[16]), *World Corporate Top R&D Investors: Paving the Way for Climate Neutrality*, https://data.europa.eu/doi/10.2760/49552.

3.2. Public support for business R&D and innovation in Korea

The aforementioned developments and the strong rise of Korean business innovation in selected fields could not be possible without dedicated government support. This section shows that the Korean government's efforts have significantly driven the rise of Korean business innovation while acknowledging a significant focus on supporting small and medium-sized enterprises (SMEs). Finally, this section describes how recent initiatives aim to alleviate some of the concerns about the partial fragmentation of government support.

3.2.1. Government support to business R&D is among the highest in OECD countries, with a heavy focus on SMEs

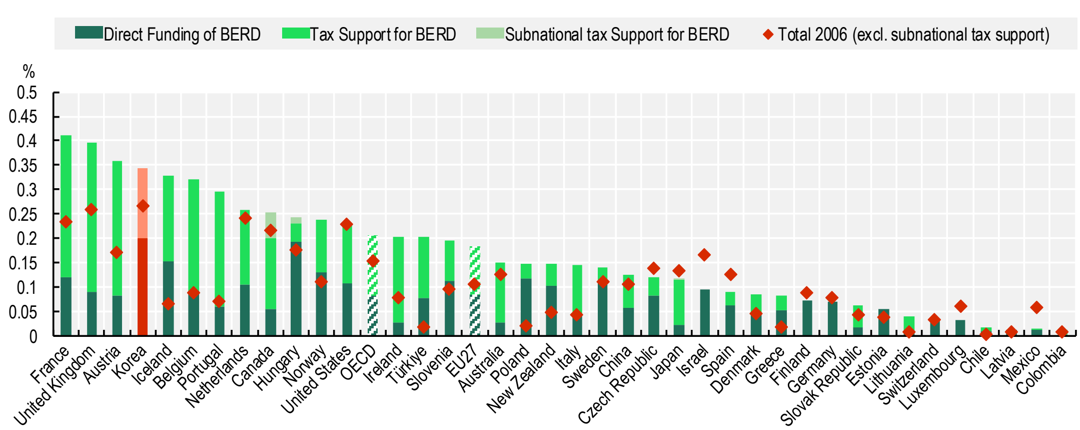
In 2020, Korea placed among the OECD countries that provide the largest level of total government support to business R&D as a percentage of GDP, at a rate of 0.29% of GDP (Figure 3.14) (OECD, 2022[17]). Most public support for business R&D is directed at SMEs. In 2019, the government financed 13.2% of all R&D conducted by SMEs. In contrast, the government financed only 1.8% of the R&D expenditures of large firms (MSIT and KISTEP, 2021[18]). Heavy focus on SMEs in public support for business R&D applies not only to direct funding but also to tax support. In line with the government's direct financing of business R&D, R&D tax breaks for SMEs are much more generous than for large firms. Specifically, tax credits for large firms are capped at 2% of R&D spending, while there is no ceiling for the R&D tax credits for SMEs. As a result, the implied tax subsidy rate for profit-making SMEs was 26% in 2020, in contrast to 2% for large firms (Box 3.1. R&D tax incentives in Korea). Nonetheless, due to the dominant role of large firms in R&D spending in Korea, the share of the total amount of R&D tax credits given to SMEs among all R&D tax credits was only 40% in 2018 (OECD, 2023[2]).

Korea is an outlier among major OECD countries in its strong focus on SMEs in R&D tax credits. With the exception of the United Kingdom, other large, developed countries provide more or less the same R&D tax incentives to large and small firms. Meanwhile, between 2007 and 2019, the importance of tax incentives increased in Korea in absolute terms, whereas the relative magnitude of tax compared to direct support remained fairly stable. As a result, R&D-related taxable income deductions for business firms amounted to KRW 2.81 trillion in 2018 (MOTOE and KIAT, 2020[19]).

Government support for SMEs in Korea encompasses a wide range of policy tools, including financing subsidies, notably business R&D; favourable access to public procurement; regulations differentiated by company size; and whole market segments reserved for SMEs. Although many of these policies may have some justification when seen in isolation, they add up to a system that supports the survival of low-productivity firms against a backdrop of regulatory complexity.

Figure 3.14. Direct government funding of business R&D and tax incentives for R&D in Korea and selected economies, 2020 (nearest year)

As a percentage of GDP



Note: Data on subnational tax support are only available for a group of economies.
Source: OECD (2022[17]), *R&D Tax Incentives (database)*, http://oe.cd/rdtax, April 2022.

Box 3.1. R&D tax incentives in Korea

Design of R&D tax relief provisions

Korea provides R&D tax relief through a hybrid R&D credit and a volume-based investment credit for machinery, equipment, and buildings (see Table 3.3).

Key features include the following:

- Under the hybrid R&D tax credit, R&D tax relief generally equals the larger of the volume-based or incremental tax off-set.
- In case of insufficient tax liability, unused credits can be carried forward for ten years (previously five years) under the hybrid R&D tax credit and for five years under the R&D investment credit.

Table 3.3. Main design features of R&D tax incentives in Korea, 2021

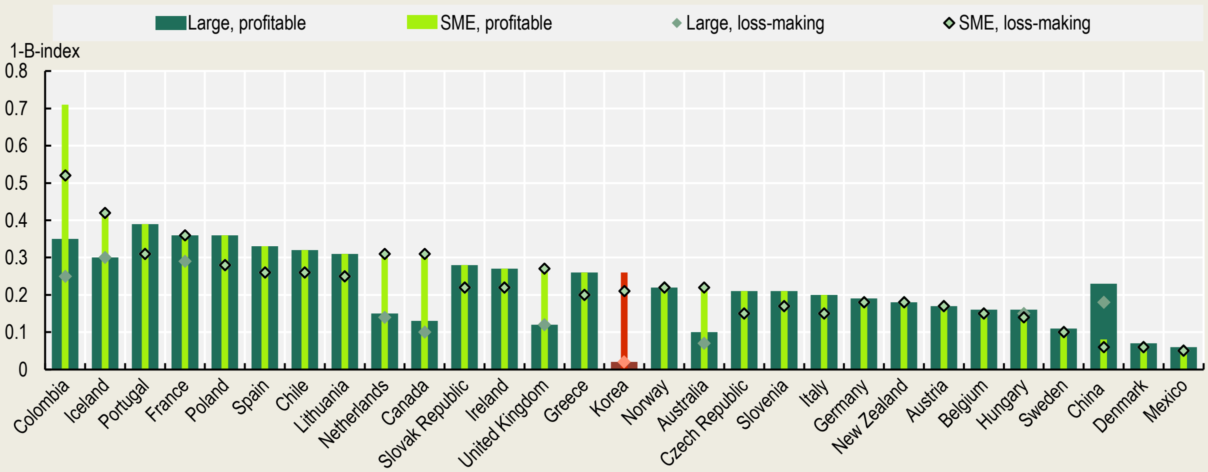
		R&D tax credit		R&D investment credit
Type of instrument		Hybrid (volume or increment)*		Volume-based
Eligible expenditures		Current		Machinery and equipment, buildings
Headline rates (%)		Volume: 0-2 (Large firm) [0.5 R&D expense-sales ratio], 8-15 (HPE), 25 (SME) GIBT**: 20-30 (Large firm, HPE), 30-40 (SME)	Increment: 25 (Large firm), 40 (HPE), 50 (SME)***	1 (Large firm), 3 (HPE), 7 (SME)
Refund		No		
Carry-over (years)		10 (carry forward)		5 (carry forward)
Thresholds and ceilings	Base amount	R&D spending in the previous year		n.a.
	Ceiling	Tax credit capped at 2% of R&D spending (Large firms)		No

Note: R&D expense ratio=R&D/revenue; HPE: High Potential Enterprise (do not qualify as SME, respect rules about being part of a group and have sales below KRW 500 billion); *The R&D tax credit equals the greater of either: 1) the volume-based tax off-set, or the 2) incremental tax off-set; **Under the Growth Industry and Basic Technology scheme available to firms with R&D aimed at New Growth and Basic technologies (235 technologies in 12 areas, including future cars, next-generation electronic information devices, energy and environment), enhanced volume-based tax credit rates apply to SMEs (30~40; 15/10 for firms losing SME status, see compendium) and to large firms and HPEs (20~30); *** 40 for firms losing the SME status. Korea also offers an income-based tax incentive for outcomes of R&D activities. This incentive is beyond the scope of this chapter. For more details, see the *OECD R&D Tax Incentive Compendium* at https://www.oecd.org/sti/rd-tax-stats-compendium.pdf and "Eligibility of current and capital expenditure for R&D tax relief" at https://www.oecd.org/sti/rd-tax-stats-expenditure.pdf.
Source: OECD (2022[17]), *R&D Tax Incentives* (database), http://oe.cd/rdtax, December 2021.

The generosity of R&D tax support in 2021

Differences in the design of R&D tax incentives drive significant variation in the expected generosity of tax relief per additional unit of R&D investment. For example, in 2022, the marginal tax subsidy rate for profit-making (loss-making) SMEs in Korea was estimated at 0.26 (0.21), above the OECD median of 0.20 (0.18) (Figure 3.15). On the other hand, the implied R&D tax subsidy rate for large firms equals 0.02 (0.02) in the profit (loss) case, well below the OECD median of 0.17 (0.15). These estimates focus on the hybrid R&D tax credit (not accounting for the enhanced tax credit rates applicable to a subset of firms under the Growth Industry and Basic Technology scheme) and the R&D investment credit.

Figure 3.15. Implied tax subsidy rates on R&D expenditures in Korea and selected economies, 2022



Note: Implied marginal tax subsidy rates, presented for different firm size and profitability scenarios, are calculated based on headline tax credit/allowance rates (see the methodology and country-specific notes), providing an upper bound value of the generosity of R&D tax support, not reflecting the effect of thresholds and ceilings that may limit the amount of qualifying R&D expenditure or value of tax relief.
Source: OECD (2022[17]), *R&D Tax Incentives* (database), http://oe.cd/rdtax (accessed on 12 June 2023).

3.2.2. Support for business R&D is in part fragmented, although recent policy initiatives are encouraging

Despite considerable and generous government support for business R&D in Korea, government support has long been under pressure to be more efficient and have more impact, as some problems, including fragmentation, have been identified. Institutionally, the three main actors of the R&D support policy for SMEs are the Ministry of Trade, Industry and Energy, the Ministry of SMEs and Start-ups, and the Ministry of Science and ICT. In 2019, these ministries administered 42.3%, 29.3% and 8.6% of the overall government budget for R&D support directed at SMEs, respectively (Ahn, Lee and Lee, 2021[20]). The ministries conduct a wide range of R&D support programmes that mostly focus on providing direct R&D subsidies or loans for SMEs (KISTEP, 2019[21]). Despite various R&D support portfolios from different ministries, R&D support policies in Korea have been assessed as highly fragmented. The government's online portal for SME support policies lists over 400 separate programmes related to technology support (Ministry of SMEs and Start-ups, 2021[22]).

On top of fragmented support programmes, the following problems have also long been identified in terms of the R&D support programmes for SMEs in Korea: 1) subsidising R&D of SMEs that lack the research capabilities to use the funds effectively; 2) widespread multiple disbursements of R&D subsidies to the same firms; and 3) support of firms that lack managerial proficiency (Ahn, Lee and Lee, 2021[20]).

Meanwhile, recent policy initiatives which envision long-term support throughout technology development and commercialisation, link government support to private investment, emphasise collaborative R&D activities and reduce the administrative burden for participating firms (Ministry of SMEs and Start-ups, 2019[23]) are still in the early phase, to be monitored and assessed.

A different and new type of government support policy relates to public procurement to enhance innovation, which has been promoted in Korea through an amendment in the Public Procurement Law in 2020.

Monitored by the Ministry of Economy and Finance, a target has been set that every public agency should spend at least 1% of its total procurement on innovative products (Lee, 2021[24]). Such products are certified by the Central Procurement Agency based on their technological excellence in order to enhance the quality of procured products and to support SMEs and venture firms. Suppliers of selected products also receive support for R&D related to developing these products (MOTIE, 2021[25]).

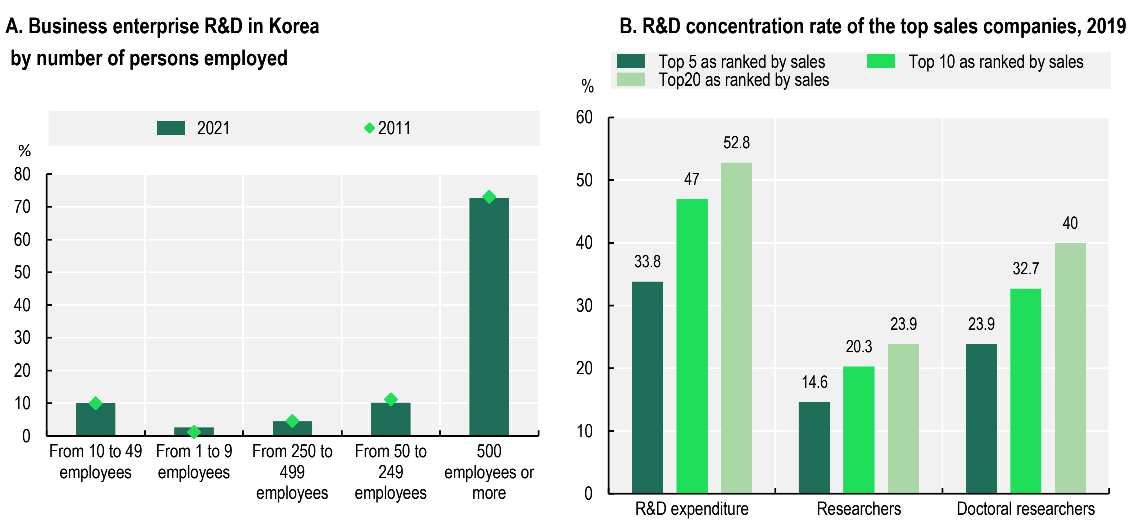
3.3. Imbalances in Korean business innovation

This section draws a more differentiated overview of Korean business innovation by showing that despite the strengths of the Korean business innovation system, several imbalances and concentration risks also exist. These imbalances persist with regard to firm size and type of industry, i.e. manufacturing and services, as well as ICT and non-ICT industries.

3.3.1. Strong concentration of R&D in large firms warrants cautious assessment of business innovation in Korea

In Korea, more than 70% of total R&D spending falls to large companies with 500 or more employees, compared with less than 14% spent by small enterprises with fewer than 50 employees (Figure 3.16, Panel A). This high concentration of business R&D spending on large firms is typical among developed countries. For example, the proportion of all business R&D expenditures falling to firms with 500 or more employees was 90.4% in Japan in 2019, 87.5% in Germany in 2017, 69.2% in the United Kingdom in 2018 and 64.8% in France in 2017 (OECD, 2021[26]). However, the exceptionally high concentration in business sector R&D spending on the largest companies is unusual among major industrialised countries like Korea. Some 33.8% of all business R&D spending fell to the five largest companies in 2019, up from 33.5% in 2014, and 47.0% to the ten largest companies, up from 44.1% in 2014 (Table 3.4) (MSIT and KISTEP, 2021[18]). Understandably, these companies also account for a large share of researchers in the business sector, such as 14.6% of the total researchers and 23.9% of doctoral researchers (Figure 3.16, Panel B).

Figure 3.16. Business R&D spending by firm size and top companies in Korea, 2019



Source: OECD (2023), "Research and Development Statistics: Business enterprise R-D expenditure by size class and by source of funds - ISIC Rev 4", *OECD Science, Technology and R&D Statistics* (database), https://doi.org/10.1787/7ce7448d-en (accessed on 11 June 2023).

Table 3.4. R&D concentration rate of top sales companies in Korea

In percentage

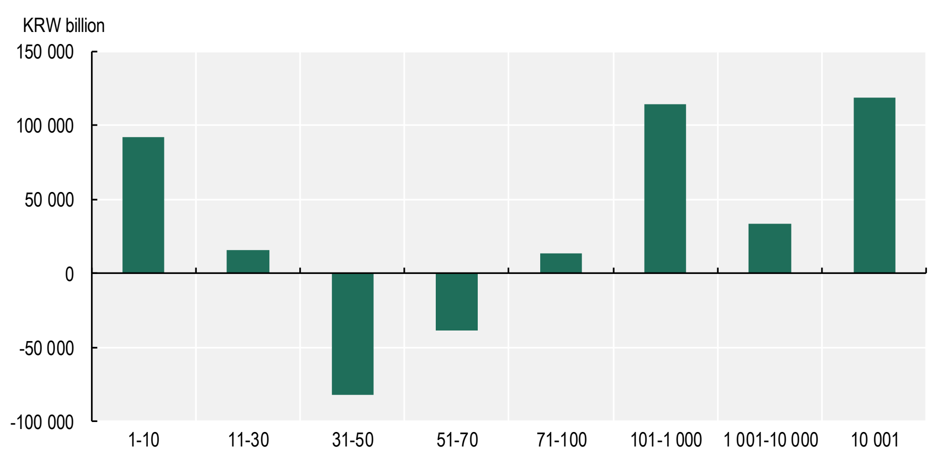
		2014	2015	2016	2017	2018	2019
R&D expenditure	Top 5	33.5	37.2	37.7	40.4	36.8	33.8
	Top 10	44.1	41.7	44.3	50.2	47.4	47.0
	Top 20	51.6	49.3	51.6	54.0	53.7	52.8
	Top 30	53.9	51.5	53.4	55.5	54.5	54.0
	Top 50	58.9	57.3	56.3	58.0	58.4	56.6
	Top 100	63.4	61.9	62.3	63.7	63.1	60.7

Source: MSIT and (KISTEP, 2019[13]), Survey of Research and Development in Korea, 2019, https://www.kistep.re.kr/reportDownload.es?rpt_no=RES0220210050&seq=res_0026P@5

This significant concentration in business R&D necessitates caution, however, when examining the overall picture of Korean business innovation. Looking at the overall trend in business innovation could risk missing the actual underlying status of business innovation in Korea. For example, the expenditure of the top 30 sales companies has risen recently, whereas the R&D expenditure of companies ranking 31st through 70th in sales has decreased year on year (Figure 3.17). Furthermore, the dominance of the global information technology (IT) giant Samsung Electronics (Box 3.2), in terms of R&D spending, is so significant, accounting for around 20% of total business R&D in the country, that it inevitably could mislead the translation of aggregated statistics in business innovation.

Figure 3.17. Fluctuations of R&D expenditure among top Korean sales companies, 2019

R&D expenditure change of top companies ranked by sales (year on year)

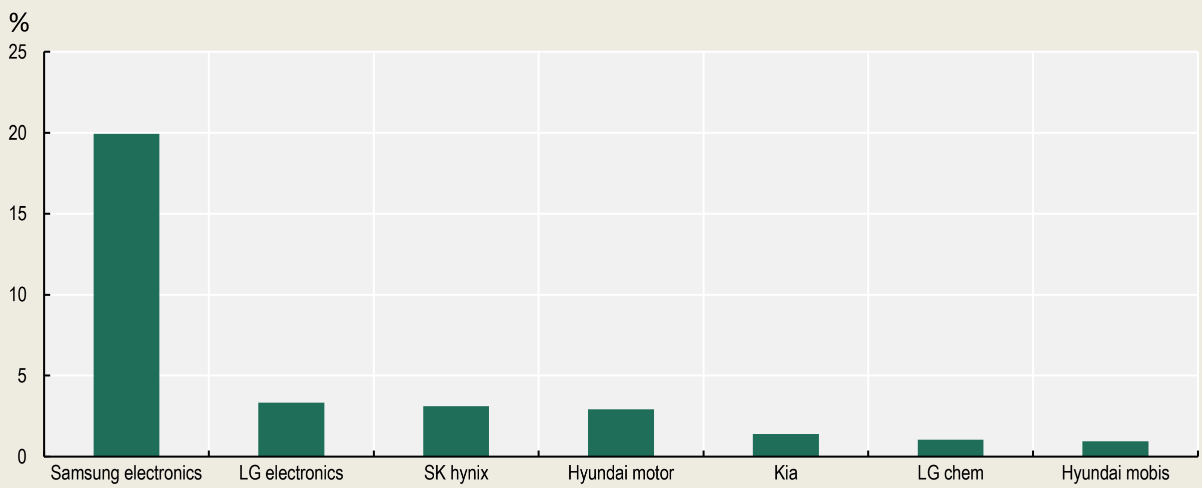


Source: MSIT and (KISTEP, 2019[13]), *Survey of Research and Development in Korea, 2019*, https://www.kistep.re.kr/reportDownload.es?rpt_no=RES0220210050&seq=res_0026P@5.

Box 3.2. The dominance of Samsung Electronics in Korean business innovation

In the Korean business R&D landscape, Samsung Electronics, a world ICT giant, is prominently leading in input (R&D expenditure), output, and commercialisation (patents and trademarks). It accounts for 2.3% of global R&D expenditures (after Alphabet), 3.6% in world IP5 family patenting (ranks top) and 1.2% in trademarking (seventh in the world) (European Commission et al., 2021[16]). From a domestic perspective, Samsung Electronics alone invested 19.9% of Korean business R&D expenditure in 2020 (Figure 3.18). As evidenced by Samsung's intensive R&D investment, the electronic and electrical equipment sector is overwhelming others in Korea, which accounts for 19.1% of all domestic business R&D expenditure.

Figure 3.18. Firm shares in Business R&D expenditure in Korea, 2020



Source: European Commission (2022[3]), *The 2021 EU Industrial R&D Investment Scoreboard*, https://iri.jrc.ec.europa.eu/scoreboard/2021-eu-industrial-rd-investment-scoreboard; (OECD, 2022[27]), *Research and Development Statistics* (database), https://oe.cd/rds.

3.3.2. The innovation divide between larger and smaller firms is more acute in Korea than in other countries

Like R&D investment, there is also a large disparity in the ratio of innovating firms across enterprise size classes in Korea. Both for product innovations and business process innovations, the proportion of innovating firms with 500 or more employees is approximately five times that of innovating firms with 10-49 employees (OECD, 2020[8]). These differences across enterprise class sizes are much more acute than in other developed countries. For example, in Germany, 23.4% of manufacturing firms with 10-49 employees, 32.7% of firms with 50-249 employees and 49.4% of firms with 250 or more employees have innovated ((Eurostat, 2021[11])).

Despite the Korean government's efforts to foster SMEs' innovative capacity – notably by increasing government R&D investment in SMEs – the role of SMEs in Korea's business innovation is relatively minor. This is partly due to large conglomerates conducting most of their R&D activities and innovation in-house. For example, expenditures for external R&D, including expenditures paid to member firms of the same conglomerate, amounted to only 6% of all R&D expenditures of Korean firms in 2019 (MSIT and KISTEP, 2021[18]). This relative amount of external R&D expenditures in Korea is much lower than in other major industrialised countries. For example, in the manufacturing sector, it was 23.7% in Germany in 2017, 17.2% in Japan in 2020, and 14.3% in the United States in 2018. However, it should be noted that there are some promising developments in the role of SMEs in Korea. In particular, manufacturing SMEs that have successfully innovated have often occupied market niches for technology-intensive products that have not received the attention of large conglomerates and have relied largely on global customers. As a result, some have established themselves as "hidden champions" (Box 3.3).

Box 3.3. Korea's hidden champions

While innovation in the Korean manufacturing sector has been dominated by large conglomerates (chaebols), the innovation activities of a different type of companies have gained importance. These companies are much smaller and focus on a much narrower range of products than large conglomerates. Still, they hold a high or dominant global market share in their products. However, public awareness of these companies tends to be low. They may, therefore, be classified as "hidden champions", as defined by Simon (2009[28]), who referred to them as companies that: 1) have high global market shares; 2) are not large; and 3) are not well-known to the general public.

Humax specialises in digital set-top boxes that connect TVs with external signals. It was founded by engineering graduates from Seoul National University and has focused on enhancing its technological capabilities and selling its products under its own brand based on in-house R&D (Kim, Sengupta and Kim, 2009[29]). The company has a strong global business presence and sells its products in almost all parts of the world (Humax, 2021[30]).

IDIS was founded by former students from the computer science department of the Korea Advanced Institute of Science & Technology (KAIST), a leading technical university, in a bid to create a global technology company. Based on its internally developed core technology, it has become a global pioneer and major competitor in digital camera surveillance systems (Lee, 2010, pp. 287-293[31]).

Suprema, founded by an engineering PhD from Seoul National University, has developed fingerprint recognition devices for security applications. It has focused on global markets from the outset, as the domestic demand for the company's products has been initially small. The company has created technologically leading algorithms that can be applied to various types of product solutions (Cho, 2012[32]). It has regularly won international product competitions and has become a global market leader in access control biometric readers (Suprema, n.d.[33]).

Commonalities of these and other Korean hidden champions include an innovation focus based on in-house R&D, driven by their founders' deep technological expertise and a strong global business orientation. As a result, such firms are becoming more numerous.

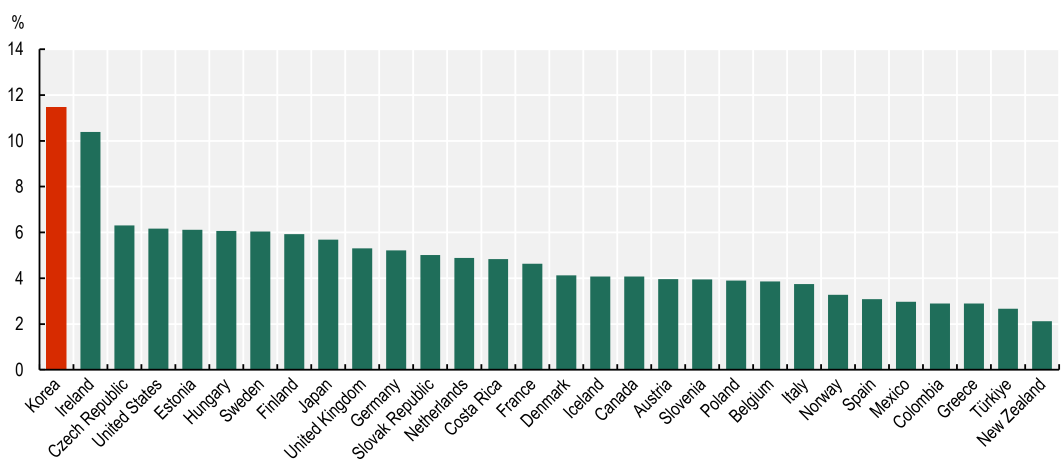
Meanwhile, the Korean government has promoted the growth of SMEs into "hidden champions". The Korean government's most notable policy initiatives include implementing the World Class 300 Project, which aimed to promote 300 world-class enterprises by stimulating SMEs' motivation and potential for growth with various support programmes, including financing, R&D and marketing, required to expand their global markets.

Source: Cho (2012[32]), *The Growth Process and Key Success Factors of Technology-Intensive Ventures: The Case of Suprema Co.*, Humax (2021[30]), *Humax Global Network*, https://dearhumax.com/en/bbs/page.php?hid=Humaxintroduce3; Kim, Sengupta and Kim (2009[29]), "How Can Non-Chaebol Companies Thrive in the Chaebol Economy?", https://doi.org/10.1080/12297119.2009.9707296; Lee (2010[31]), *Small Giants: Korea's Strong SMEs*; Simon (2009[28]), *Hidden Champions of the 21st Century: Success Strategies of Unknown World Market Leaders*, https://doi.org/10.1007/978-0-387-98147-5; Suprema (n.d.[33]), *Suprema, Who We Are, Proven Leader in Access Control, Time & Attendance and Biometric Solutions*, https://www.supremainc.com/en/about/suprema.asp.

3.3.3. Korea's ICT industry has achieved remarkable growth and leads globally

Korea's ICT industry is outstanding in the Korean industrial landscape and against comparable advanced economies on the global stage. Korea ranked the highest in ICT value added (11.46%; see Figure 3.19) and third in the share of patents in ICT(18%; see Figure 3.20) among OECD countries (OECD, 2017[34]). Korea also ranked fourth in the utilisation of industrial robots (Figure 3.21). According to the Bank of Korea (2017), the real GDP of the Korean ICT industry accounted for 10.9% of whole GDP (Table 3.5). The real GDP growth rate of the ICT industry was 7.1% in 2017 compared to 2.6% for the non-ICT industry, and the contribution rate of the ICT industry to GDP growth amounted to 18.5% in 2017. For the previous five years (2012-17), the real GDP growth rate of the ICT industry was 5.5% per year, exceeding the overall industrial growth rate of 3.0%. As such, the ICT industry continues to play a leading role in Korea's economic growth.

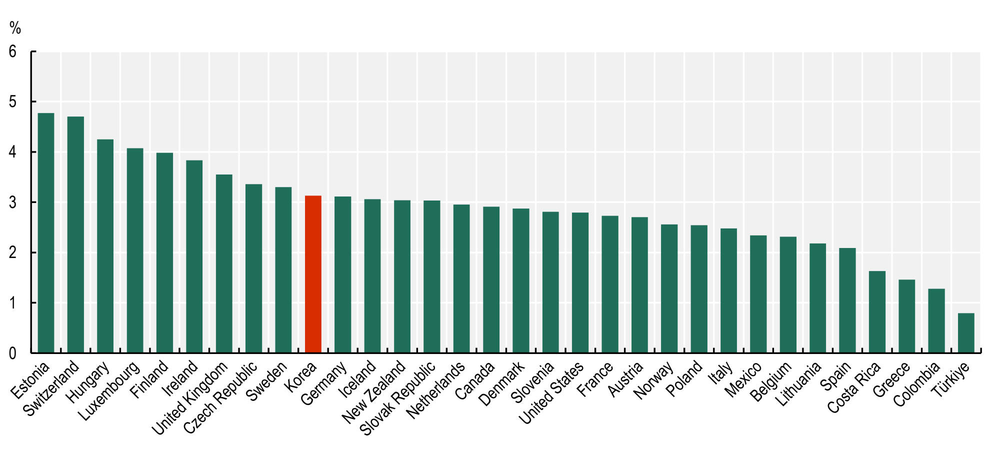
Figure 3.19. Value added of the ICT sector in Korea and OECD countries, 2018



Source: OECD (2023), "STAN Industry ISIC Rev. 4", *STAN: OECD Structural Analysis Statistics* (database), https://doi.org/10.1787/data-00649-en (accessed on 10 June 2023).

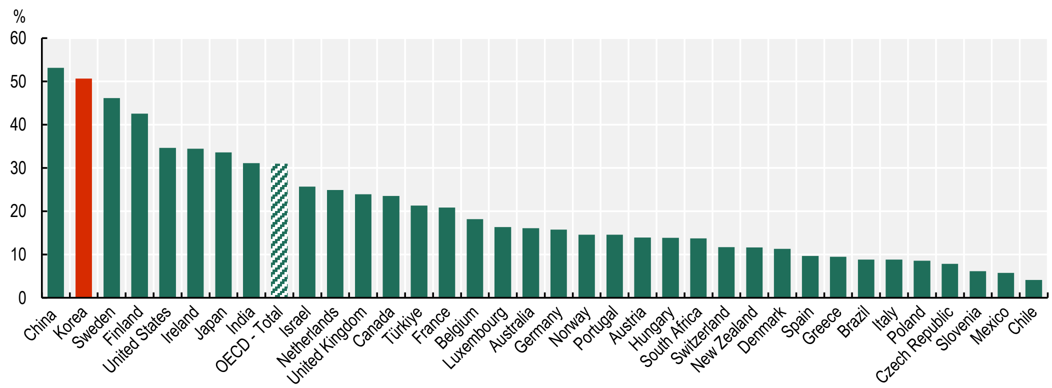
Figure 3.20. Specialisation in ICT-related patents in Korea and selected economies, 2016-19

Patents in ICT as a percentage of total IP5 patent families



Source: OECD (2023), "STAN Industry ISIC Rev. 4", *STAN: OECD Structural Analysis Statistics* (database), https://doi.org/10.1787/data-00649-en (accessed on 10 June 2023).

Figure 3.21. Top-ten countries with the highest number of operational industrial robots, 2016-19



Source: OECD Going Digital Toolkit, based on the OECD STI Micro-data Lab, http://oe.cd/ipstats (accessed on 11 June 2023).

Table 3.5. Korea's GDP growth rate and contribution of the ICT industry, 2011-17

In percentage

Type	2011	2012	2013	2014	2015	2016	2017
ICT industry GDP growth rate (real)	14.8	3.1	6.6	5.1	3.1	5.7	7.1
Non-ICT industry GDP growth rate (real)	2.3	2.3	2.7	3.0	2.6	2.4	2.6
ICT industry as a percentage of GDP (real)	9.6	9.7	10.0	10.2	10.2	10.5	10.9
ICT industry's contribution to GDP	34.2	11.8	20.3	13.3	9.2	15.8	18.5

Source: Bank of Korea (2017).

Table 3.6. Korea's top-ten manufacture exports, 2019-20

In USD million

	2019		2020	
1	Semiconductors	93 930	Semiconductors	99 177
2	Automobiles	43 036	Automobiles	37 399
3	Petroleum products	40 691	Petroleum products	24 168
4	Automobile parts	22 535	Marine offshore structures and parts	19 749
5	Flat panel displays and sensors	20 657	Synthetic resin	19 202
6	Synthetic resin	20 251	Automobile parts	18 640
7	Marine offshore structures and parts	20 159	Flat panel displays and sensors	18 151
8	Steel plates	18 606	Steel plates	15 997
9	Wireless communication devices	14 082	Computers	13 426
10	Plastic products	10 292	Wireless communication devices	13 184

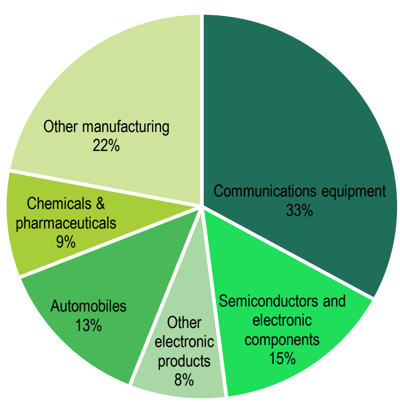
Source: Korean export customs data, https://www.index.go.kr/unity/potal/main/EachDtlPageDetail.do?idx_cd=2455.

The ICT industry has led to the trade surplus of Korean industry. In 2017, ICT exports amounted to USD 197.6 billion (US dollars), accounting for 34.4% of total exports (USD 573.7 billion). As a result, the trade surplus of the ICT industry was USD 95.5 billion, leading to the country's overall trade surplus (USD 95.22 billion; non-ICT industries suffered a USD 290 million deficit). The top-ten export items of all industries in 2020 (Table 3.6) included semiconductors, flat panel displays, computers and wireless communication devices. In particular, semiconductors ranked first, with USD 99.2 billion; computers ranked ninth, with USD 13.4 billion; and wireless telecom equipment ranked tenth, with USD 13.2 billion.

3.3.4. The widening discrepancy in R&D and productivity between Korea's ICT and non-ICT industries is of concern

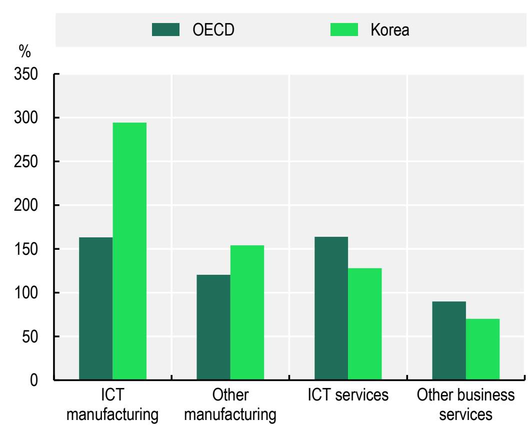
The remarkable growth and strength of Korea's ICT industry reveal a widening discrepancy between ICT and non-ICT industries in various aspects. Business R&D concentration in Korea is outstanding not only across different firm sizes but across industries. In particular, business R&D concentration in the ICT industry is as conspicuous as the extent of business R&D concentration in large firms. In the manufacturing sector, no less than 56% of all R&D spending in 2019 fell to electronic components, computer, visual, sounding and communication equipment (broadly covering the IT and electronics industries), with 33% being spent by the communications equipment (mobile phone) industry alone (Figure 3.22). Other major R&D spenders are the semiconductor and electronic component industry (15%) and the automobile industry (13%). In contrast, the combined proportion of the chemical and pharmaceutical industries (9%) is modest, considering their generally high R&D intensity.

Figure 3.22. Manufacturing sector R&D in Korea by industry, 2019



Source: MSIT and KISTEP (2021[18]), *Survey of Research and Development in Korea, 2019*, https://www.kistep.re.kr/reportDownload.es?rpt_no=RES0220210050&seq=res_0026P@5.

Figure 3.23. Sector productivity relative to total productivity in Korea and OECD, 2015



Note: "ICT manufacturing" includes the manufacture of computer, electronic and optical products. "ICT services" include publishing, telecommunication and IT services. "Other business services" excludes the housing sector.
Source: OECD (2020[35]), *OECD Economic Survey: Korea 2020*, https://doi.org/10.1787/2dde9480-en.

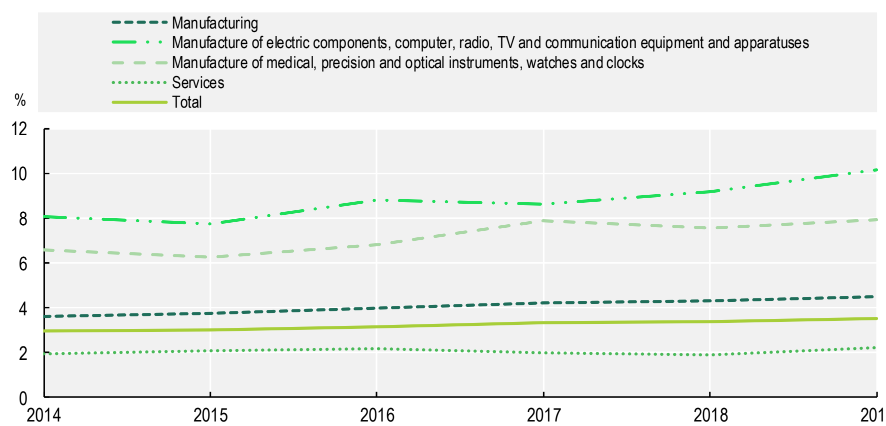
The disparity in innovation activity, including R&D investment across varying industries, could lead to increased disparity in productivity. In effect, the significant concentration on business R&D in the ICT industry mirrors the productivity gap between ICT and other industries. While the productivity of Korean ICT manufacturing business to total productivity (294%) is much higher than the OECD average (163%), the productivity of others remains at half of ICT manufacturing (154%) (Figure 3.23) (OECD, 2020[35]).

3.3.5. Stark discrepancies in R&D and productivity between manufacturing and services industries also exist

In Korea, almost 90% of all business R&D in Korea is spent on the manufacturing sector. The share of non-manufacturing R&D decreased from 12.5% in 2011 to 10.4% in 2015 before recovering to 12.5% again in 2019 (Figure 3.24). While the manufacturing sector generally plays an important role in business R&D across industrialised countries, the strong concentration of R&D on manufacturing firms in Korea stands out in international comparison. The average proportion of business R&D falling to manufacturing in the five largest developed economies (United States, Japan, Germany, United Kingdom and France) was 70.8% in 2016 (calculated from (OECD, 2023[2])).

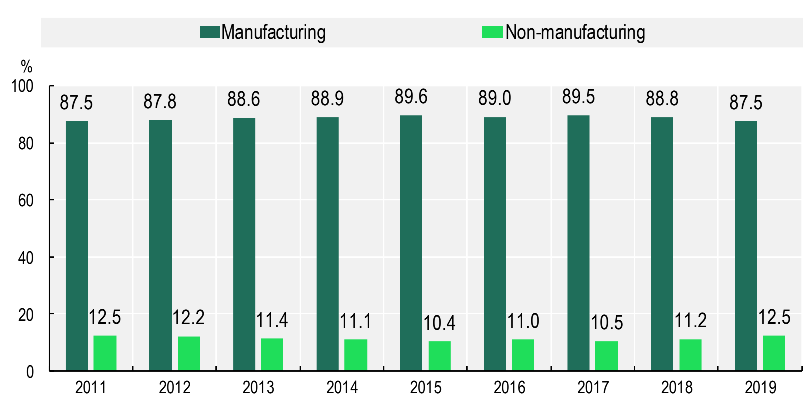
Furthermore, Korean manufacturing firms spend much more on R&D in relation to their revenue size than their counterparts in the service sector. In 2019, R&D intensity (the ratio between R&D expenditures and sales) was 4.49% in the manufacturing sector and 2.21% in the service sector (Figure 3.25) (MSIT and KISTEP, 2021[18]). Moreover, R&D intensity in manufacturing has risen over the last five years, from 3.63% to 4.49%, while the service sector has stagnated. In the service sector, the largest R&D spender is the "information service publishing" industry, which mainly consists of software companies (Figure 3.26). Most of the remaining R&D spending in services falls to other ICT services, including broadcasting, advertisement, R&D services, engineering and technical services. These service industries are thought to rely to a great extent on manufacturing business customers. In other words, substantial parts of service R&D appear to be linked to innovation in the manufacturing sector. The dominance of the manufacturing sector in business R&D in Korea thus may be even stronger than the overall sectoral composition of R&D spending suggests.

Figure 3.24. R&D expenditure rate to sales by major industries, Korea, 2014-19



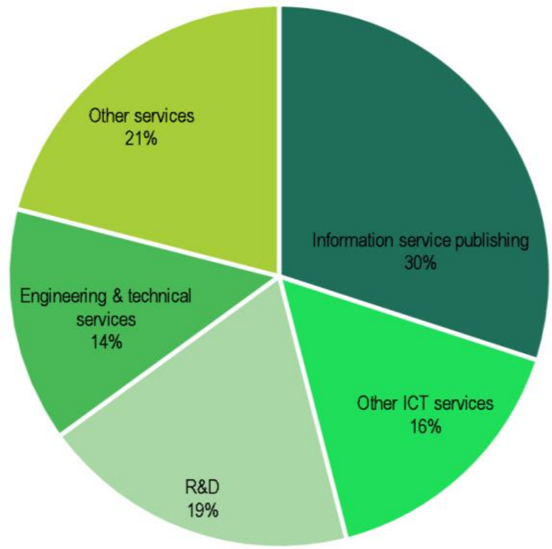
Source: MSIT and KISTEP (2021[18]), *Survey of Research and Development in Korea, 2019*, https://www.kistep.re.kr/reportDownload.es?rpt_no=RES0220210050&seq=res_0026P@5.

Figure 3.25. Business enterprise R&D in Korea by sector, 2011-19



Source: MSIT and KISTEP (2019[13]), *Survey of Research and Development in Korea, 2019*, https://www.kistep.re.kr/reportDownload.es?rpt_no=RES0220210050&seq=res_0026P@5.

Figure 3.26. Service sector R&D in Korea by industry, 2019



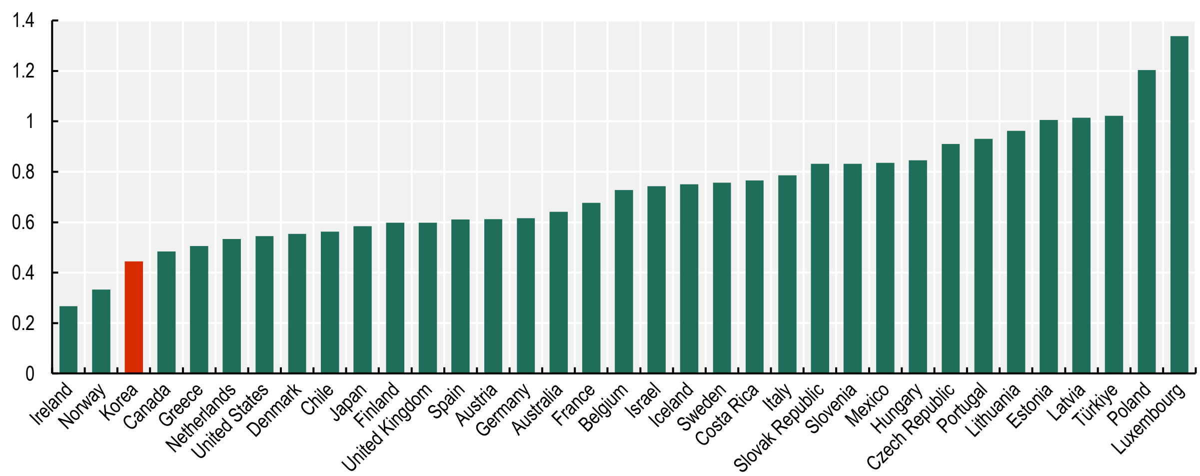
Source: MSIT and KISTEP (2021[18]), *Survey of Research and Development in Korea, 2019*, https://www.kistep.re.kr/reportDownload.es?rpt_no=RES0220210050&seq=res_0026P@5.

The gap between Korea's manufacturing and service industries does not stop at R&D investment and spans various aspects of innovation. First, a wide productivity gap exists between Korea's manufacturing and service industries (Figure 3.27). The sector productivity gap in Korea is among the highest in the OECD (OECD, 2023[6]). Meanwhile, a robust productivity-wage premium exists in OECD countries (Berlingieri, Calligaris and Criscuolo, 2018[36]). Higher wages are paid by more productive firms; thus, a close link can be observed between productivity and wages. Therefore, the productivity gap identified between Korea's manufacturing and service sectors matches equally pervasive wage gaps. Adding the additional layer of imbalance between large and small firms on top of the sectoral productivity gap opposes large manufacturing firms to SMEs in the service sector. Combining the size and sectoral dimensions from the within-industry analysis and linking them to wages, it appears that productivity gains overwhelmingly accrue to large manufacturing firms. Productivity in small manufacturing and service firms of all sizes is low compared to large manufacturing firms, and the gap is larger in Korea than in other OECD countries on average (Figure 3.28, Panel A). Wage gaps largely reflect the productivity gaps (Figure 3.28, Panel B) (OECD, 2023[6]). Meanwhile, lack of productivity can also influence competitiveness and the Korean service industry's advantage in terms of global integration. Korea ranked 7th among manufacturing hubs in global value chains and only 21st among services (OECD, 2021[37]).

3.3.6. The servicification of manufacturing can offer great potential but remains largely untapped

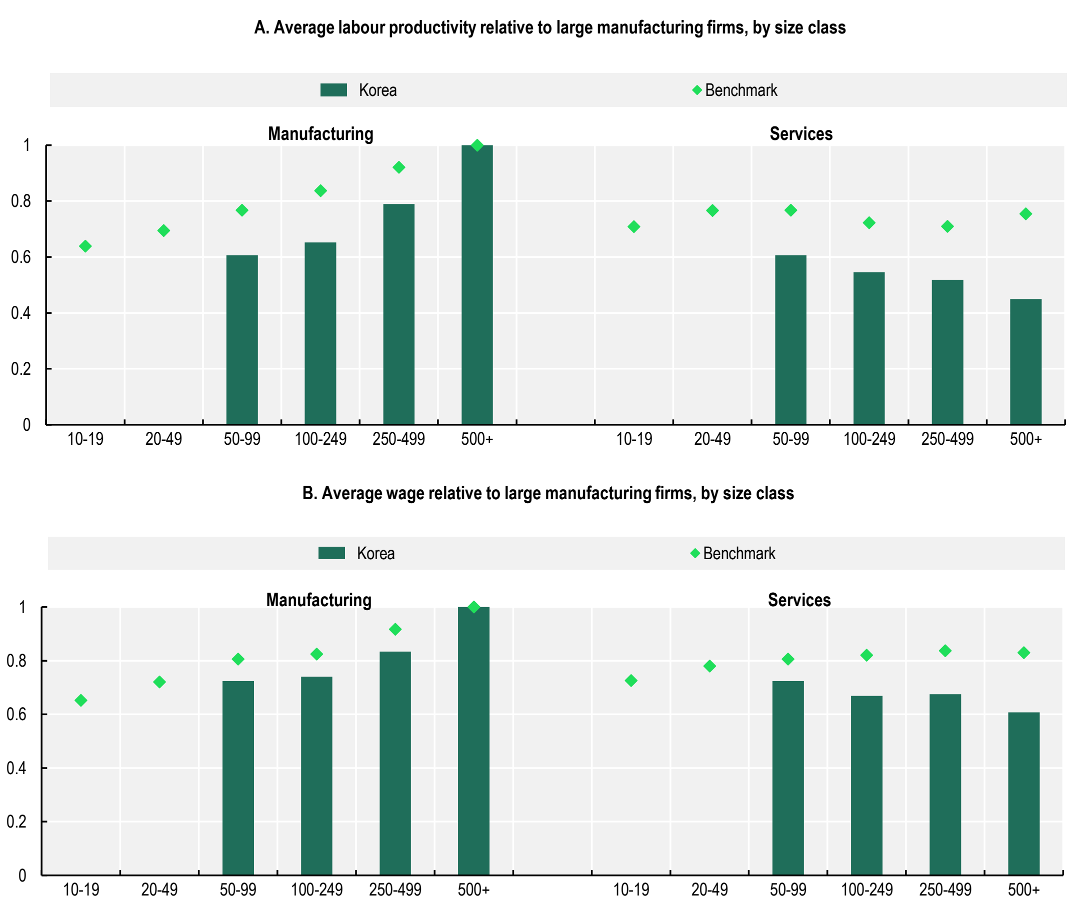
With the development of ICT technologies, services are increasingly embedded in manufacturing products as manufacturing firms increasingly rely on services, either as inputs, as production activities within a firm, or as outputs sold bundled with goods (Miroudot and Cadestin, 2017[38]). This phenomenon is known as "servicification" of the manufacturing industry. Korea has great potential for this servicification (OECD, 2020[35]). For instance, cell phone manufacturers can bundle their products with telecommunication services to allow users to install apps, generating additional service transactions. In this regard, Korea can benefit from the manufacturing sector itself to develop some value-added services. However, data show that Korea has not fully tapped into the potential of servicification. In effect, the contribution of domestic services to manufacturing exports is one of the lowest among OECD countries at 15%, while the OECD average is 28% (OECD, 2021[39]).

Figure 3.27. Labour productivity in services relative to manufacturing in Korea and OECD countries, 2015



Source: OECD (2021[37]), *Inclusive Growth Review of Korea: Creating Opportunities for All*, https://doi.org/10.1787/4f713390-en.

Figure 3.28. Average labour productivity and wages relative to large manufacturing firms in Korea, 2015



Source: OECD (2021[37]), *Inclusive Growth Review of Korea: Creating Opportunities for All*, https://doi.org/10.1787/4f713390-en.

3.4. Ongoing developments, achievements, and a way forward

This section discusses developments relevant to the Korean business innovation system and industry structure more generally, which is highly concentrated in the ICT and manufacturing industries. The section focuses on the emergence of biotechnology, which holds vast potential for Korea and constitutes a significant shift to emerging non-ICT technologies. In addition, it alludes to the importance of not neglecting high-value-added and knowledge-intensive services to counter the prevalent imbalance.

3.4.1. Korea relies the most highly on ICT industries among OECD countries, but new technology-based industries, such as biotechnology, are emerging

Korea has strived to diversify its industry landscape from ICT-centred manufacturing to knowledge- and high-tech-based industries with more diversity. Despite continued reliance on the ICT industry, the growing presence of the biotech industry in Korea provides a potential pathway for advancing toward a more diversified and knowledge-based economy. Korea envisioned promoting the biotech industry decades ago; its move started in the early 1980s with the Biotechnology Support Act (see Box 3.4), which provided the legal framework for governing support policies in the field of biotechnology.

Box 3.4. Korea's Biotechnology Support Act

The purpose of Korea's Biotechnology Support Act is to develop and support biotechnology more efficiently by laying the foundation for biotechnology research and to contribute to the sound progress of the national economy by facilitating the industrialisation of the technology.

The Minister of Science and ICT shall formulate the basic plan for biotechnology support (hereafter, the "basic plan"). The basic plan includes the following:

- comprehensive plans and guidelines on fundamental studies of biotechnology and the promotion of studies for industrial application thereof
- guidelines related to a comprehensive development plan and efficient utilisation of human resources necessary for research in biotechnology
- plans and guidelines related to research in biotechnology and the international exchange of talents and technology.

The Council for Comprehensive Biotechnology Policy shall be formed under the authority of the Minister of Science and ICT for the management of affairs relating to the establishment of the basic plan and its execution and co-ordination.

The Government of Korea shall promote co-operative activities among academia, research institutes and industry for efficient research and technological development in biotechnology. The Government of Korea may take policy steps to provide assistance in matters falling under each of the following subparagraphs in order to vitalise the R&D of biotechnology and to facilitate the industrial application of the results thereof:

- matters concerning assistance in the production of goods using new technology
- matters concerning R&D aimed at facilitating the industrial application of the results of biotechnology research and the building of regional R&D bases
- matters concerning assistance in start-ups and SMEs involved in biotechnology.

The Government of Korea shall endeavour to promote R&D by gathering information for biotechnological research and distributing it to related organisations.

The Government of Korea shall establish a system regarding safety and clinical tests for biotech products.

Source: Korea Legislation Research Institute and Korea Law Translation Center (2021[40]), *Biotechnology Support Act*, https://elaw.klri.re.kr/eng_service/lawView.do?hseq=60046&lang=ENG.

The growth of the Korean biotech industry has been impressive, with many Korean biotechnology firms now taking leading positions around the globe. Overall, the biotech industry has become one of Korea's major industries. According to the latest data from the Ministry of Trade, Industry and Energy, Korean biotech industry production increased to KRW 1 749.23 billion in 2020, a significant jump, equivalent to 38.2% over the previous year, the greatest increase since the statistics were collected and announced (see Table 3.7, section A). Moreover, biotech industry exports rose 53.1% in 2020 (see Table 3.7, section B). This remarkable increase has been accompanied by a rapid increase in employment in the industry; in 2020, employment in biotech rose by 10% (Ministry of Trade, Energy and Industry, 2021[41]).

Table 3.7. Progress in Korea's biotechnology industry, 2016-20

Biotech industry production and domestic demand, 2016-20, in KRW 100 million

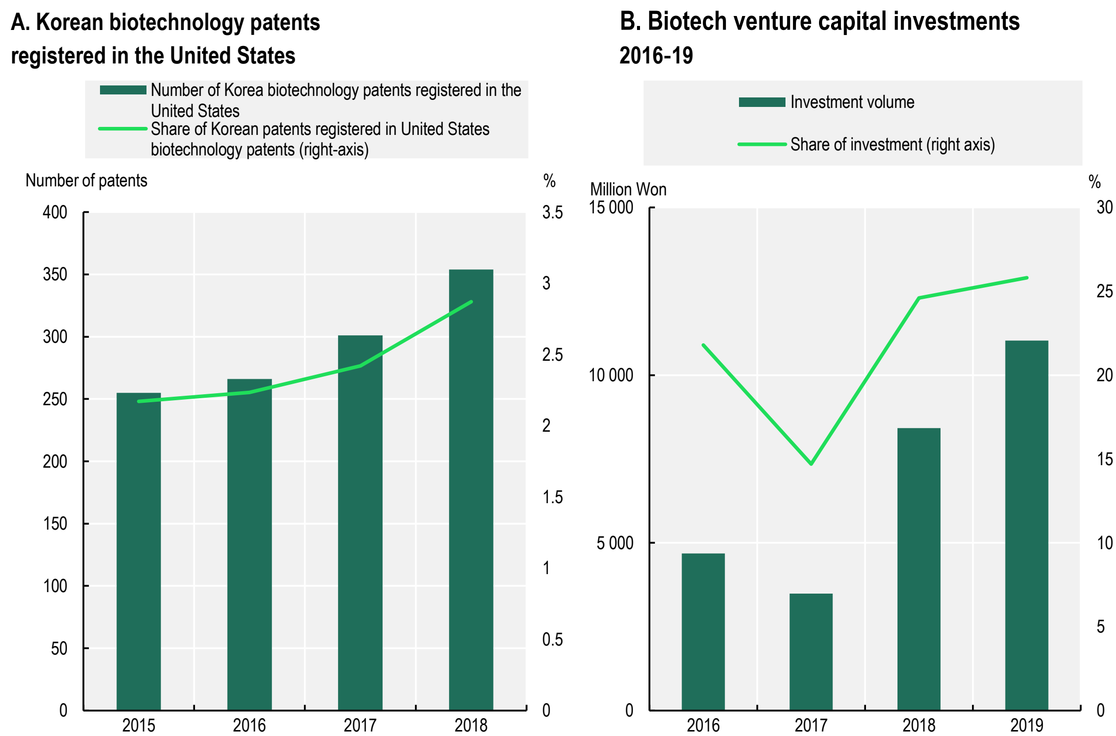
	A. Biotech industry production and domestic demand, 2016-20, in KRW 100million						
		2016	2017	2018	2019	2020	Average annual rate of change
Production (Domestic sales + exports)	Amount	92 611	101 457	106 767	126 586	174 923	
	Rate of change	8.9%	9.6%	4.5%	19.3%	38.2%	17.2%
Domestic demand (Domestic sales + imports)	Amount	60 898	65 466	70 966	81 836	98 189	
	Rate of change	8.2%	7.5%	8.4%	15.3%	20.0%	12.8%
B. Biotech industry exports, 2016-20, in KRW 100 million							
		2016	2017	2018	2019	2020	Average annual rate of change
Export	Amount	46 310	51 684	52 382	65 414	100 158	
	Rate of change	8.0%	11.6%	1.4%	24.9%	53.1%	21.3%

Source: Ministry of Trade, Energy and Industry (2021[41]), *Ministry of Trade, Energy and Industry Announcement of 2020 Bioindustry Survey Results*, http://www.motie.go.kr/common/download.do?fid=bbs&bbs_cd_n=81&bbs_seq_n=165037&file_seq_n=1.

3.4.2. Public R&D investment in biotechnology has led to the rapid increase of Korean firms' biotech patents and the creation of start-ups

Public R&D investment in biotechnology has played a critical role in creating Korea's robust bio-industry ecosystem. Government R&D investment in biotechnology increased markedly from USD 1.2 billion in 2007 to USD 3.4 billion in 2016. Biotechnology investment in government R&D accounted for 15.7% of whole government R&D spending in 2016, rising to 19.2% in 2020. Moreover, the Korean government has chosen the biotech industry as one of three innovative growth engines ("Big 3"), along with system semiconductors and future vehicles. The government has prioritised its policy measures, including R&D, tax, and regulation reform, to drive the growth of the Big 3 industry. The government planned to invest USD 5.2 billion in 2022, a 42.7% increase from 2021. Government support for the biotech industry stretches the whole innovation cycle, from technology development, authorisation and production to market entrance. Sustaining the government's strong support for R&D has yielded active patent applications and high-impact research performance (Figure 3.29). On top of academic and technological development, strong and continuing government investment has played a role in supporting entrepreneurs in creating and expanding biotechnology-related businesses, resulting in the rise of biotech venture capital investments as well (Figure 3.29). The number of biotech start-ups created in Korea was 140 in 2010, increasing to 440 in 2016. As a result, the Korean biotech industry has become competitive around the globe; Korea ranked second in terms of the production capacity of biomedicine in 2020 (Ministry of Trade, Energy and Industry, 2021[41]).

Figure 3.29. Development of Korea's biotechnology industry



Source: Ministry of Science and ICT (2021[42]), *Biotechnology 2020 in Korea*, https://www.khidi.or.kr/board/view?pageNum=1&rowCnt=3&no1=&linkId=48855931&menuId=MENU02296.

Table 3.8. The number of SCI paper publications in Korea, 2013-17

	2013	2014	2015	2016	2017
Number of publications	52 827	55 791	58 832	60 471	61 163
Total number of publications worldwide	1 572 889	1 622 978	1 670 162	1 733 431	1 790 016
Percentage of global publications	3.36%	3.44%	3.52%	3.49%	3.42%
World ranking	12	12	12	12	12

Source: Ministry of Science and ICT (2021[42]), *Biotechnology 2020 in Korea*, https://www.khidi.or.kr/board/view?pageNum=1&rowCnt=3&no1=&linkId=48855931&menuId=MENU02296.

Meanwhile, the competitiveness of Korea's biotech industry was particularly evident during Korea's response to COVID-19. Korea was one of the first countries to succeed in developing and exporting COVID-19 diagnostic test kits shortly after the outbreak. The accumulated experience in developing diagnostic test kits and the prompt response by the government contributed to establishing a system for an early diagnosis of COVID-19. Korean SMEs specialised in diagnosis and emergency screening had developed the capacity to develop diagnostic test kits for the swine flu and Middle East Respiratory Syndrome outbreaks in past decades. In the meantime, the Ministry of Food and Drug Safety approved the COVID-19 diagnostic test kits by emergency use authorisation, which shortened the duration of the authorisation process by approximately 150 days. As a result, Korean biotech SMEs supplied 190 million COVID-19 diagnostic test kits to 150 countries between April and August 2020. In addition, the Ministry of Food and Drug Safety approved 166 diagnostic reagent products, while the United States approved 16 products in the same period.

3.4.3. Korea's biotech industry has huge potential, notably from the perspective of information technology-biotechnology convergence

The biotech industry in Korea has huge potential to grow into a top-notch industry in the world with a clear edge over competitors. The world's number one ICT technology can provide enormous opportunities for the future growth of the biotech industry in Korea, given that biotechnology (BT) and IT are converged in technological development and the application of technology, notably in cases such as mobile medical devices. On top of its competitive ICT technology, Korea is ranked as number one in the electronic medical records penetration rate, which could be the foundation for data-driven medical service and research, resulting from one of the most efficient and strongest universal health insurance systems. Even though the Korean biotech industry has grown remarkably, it faces some challenges (see Box 3.5). In order to become a real powerhouse in the biotech industry on the global stage, Korea's biotech business should make strong efforts to overcome these challenges.

Box 3.5. Challenges of the Korean biotech industry

Despite the outstanding growth of Korea's biotech industry, many biotech firms have pointed out major challenges and hurdles they need to overcome to advance to become a global leader in the field. Several policy initiatives have been developed by the Korean government, including the Innovative Strategy on the Bio-health Industry (2019), which presents a strengths, weaknesses, opportunities and threats (SWOT) analysis. Across different aspects that comprise the competitiveness of the biotech industry, some challenges include:

- Even leading Korean biotech firms suffer from a lack of financial resources compared to top global pharmaceutical companies. Because of this, many big Korean biotech firms have decided to export intermediary technology rather than focus on novel drug development. In fact, one of the world's number one pharmaceutical companies, Lauche, is investing KRW 13 trillion, while domestic top-ten companies in Korea are investing KRW 1 trillion combined.
- Health practitioners in hospitals aim to collaborate with academia on research, while stakeholders in academia appear to have a strong interest in using clinical infrastructure in hospitals. However, the biotech industry in Korea has not yet fully matured in terms of industry-academia and hospital collaboration, which could be critical in technology transfer and commercialisation. Some institutional hurdles still hinder close collaboration. For example, while doctors in private hospitals in the United States can create businesses, it is forbidden by law in Korea.
- Traditionally, the biotech industry in Korea has been strictly regulated to protect customers' lives and health. As a result, Korean pharmaceutical companies have to go through a longer and more time-consuming process to obtain a licence for novel health and bioproducts.

Source: Government of Korea (2019[43]), *Innovative Strategy on the Bio-health Industry*, http://www.mohw.go.kr/eng/nw/nw0101vw.jsp?PAR_MENU_ID=1007&MENU_ID=100701&page=1&CONT_SEQ=349515.

3.4.4. Although Korea has not achieved notable success, it has promoted its service industries with various policy measures

The Korean government has introduced numerous measures since the 2000s to enhance the competitiveness of the service industry. It is important to highlight some of these measures to understand the ongoing developments and identify what needs to be done going forward. This section will highlight some of the major policy measures, along with some encouraging developments in knowledge-based service industries and the creative industry[3].

First, the Korean government has worked to level the playing field between its manufacturing and service industries, given the imbalance that resulted from the government's previous prioritisation of the manufacturing industry. In July 2019, the Ministry of Economy and Finance announced a plan to provide the service sector with the same level of fiscal and financial support as the manufacturing sector in order to promote service R&D, service standardisation and service-manufacturing convergence (MOEF, 2019[44]). The plan aimed to provide the same level of support, operate under the same tax rules and address the regulatory barriers faced by service industries to allow young firms and start-ups to emerge.

For example, the support policies announced for strategic industries selected by the government – such as future cars, bio-health, smart industry industrial complex, fin-tech, new energy industry, smart cities, smart farms and drones – should balance support for both manufacturing and services. Furthermore, the support should align with broader inclusiveness objectives for society, such as labour market and skill policies. Government support policies could ensure that innovation and activity in emerging sectors are not discouraged or displaced.

In 2019, Korea also introduced a regulatory sandbox, notably including ICT-industry convergence and financial innovation (OECD, 2023[6]).[4] The introduction of the regulatory sandbox is particularly significant for the service industry, as the legacy regulations that could favour incumbents over new innovators have often been cited as a hindrance to the industry's lagging competitiveness. The regulatory sandbox can be a strategic approach for new innovations to enter the service industry by providing new opportunities for innovative business models and firms.

It is worth elaborating on the entire process of the regulatory sandbox to highlight its significance in the Korean context, where relatively heavy regulatory state rules exist for the service industry. Under the sandbox programme, companies that want to introduce a new business model can submit proposals and receive a response in no later than 30 days if the proposal is subject to regulation. If there is a regulation that conflicts with the proposal, the applicant may be able to obtain temporary permission or a regulatory exception for demonstrations or a declining answer if, for example, there are issues relating to safety that cannot be resolved. The temporary permissions are for two years and can be renewed for another two years. If regulatory improvements are initiated, they can obtain additional extensions until the relevant regulation is revised.

By December 2022, 860 cases had been approved. Of these, 96 were given temporary permissions, 717 exemptions for demonstrations, and 47 cases were resolved by government officers proactively engaging with policy recommendations (for example, changing internal guidelines before presenting the issue before a deliberative committee to make the decision or give advice).

Building upon the successful implementation of the regulatory sandbox would pave the way for broader and general regulatory reform, mainly for the service industry and industry in general. The OECD's 2018 Product Market Regulation Index indicates that Korea's regulations are the sixth-most stringent among OECD countries. Moreover, regulations weigh more heavily on services, with adverse impacts on SMEs, given their concentration in the sector. Further tailoring regulations to company size would help reduce the burden on SMEs, which tend to have less capacity to conform to regulatory standards. In addition, regulatory reform should include a comprehensive negative-list system and expanded use of regulatory sandboxes, which facilitate the creation of firms using new technologies and producing new goods and services (OECD, 2022[45]).

3.4.5. The emergence and growth of several knowledge-based service industries are encouraging

The Korean government has prioritised its policy to promote the service industry, focusing on a few high-value-added service industries, such as healthcare, education, culture and software (SW). This section takes a deeper approach to analysing the SW and culture industries.

The estimated domestic production of software in 2020 (Table 3.9) amounted to KRW 66.4 trillion, representing a 7.1% increase from the previous year. From 2016 to 2020, the industry demonstrated annual growth of 7.7%, with package SW showing the highest growth and IT services showing the least growth (Ministry of Science and ICT, 2021[46]; Software Policy Research Institute, 2021[47]) (Table 3.9, Section A). IT services accounted for the highest proportion of total production, with 59.0%. Regarding SW exports, from 2016 to 2020, Korean SW industry exports grew by an annual rate of 9.6%. In particular, the game SW sector showed a very strong growth rate of 18.2% during the same period (Ministry of Science and ICT, 2021[48]; Software Policy Research Institute, 2021[47]) (Table 3.9, Section B). Some recent developments aimed at building better framework conditions for promoting the software industry, ranging from nurturing talents to streamlining the regulations on data use, are encouraging.

Table 3.9. Progress in Korea's software industry, 2016-20

A. Domestic software industry production, 2016-20, in KRW trillion						
	2016	2017	2018	2019	2020	Compound annual growth rate (2016-20)
Package software	7.6	8.9	10.3	12.2	13.1	14.8%
IT services	31.8	33.7	34.9	37.7	39.2	5.4%
Game software	10	11.4	11.9	12	14.1	8.9%
Total	49.3	54	57.1	62	66.4	7.7%
B. Domestic software industry exports, 2016-20, in KRW trillion						
	2016	2017	2018	2019	2020	Compound annual growth rate (2016-20)
Package software	9.4	10.3	10.4	12.4	9.5	0.3%
IT services	61.1	61.5	63.2	72.3	75.1	5.3%
Game software	32.8	52	62.4	63.4	64	18.2%
Total	103.2	123.8	136	148.1	148.6	9.6%

Note: A. Software production statistics are the sum of software item sales and differ from the company's total sales. 2020 figures are tentative values based on the ICT Major Item Trend Survey (monthly). B. The provisional value for 2020 is based on the Software Export Statistics Survey (monthly)

Source: A. Ministry of Science and ICT (2021[46]), *ICT Status Survey (2021.5), ICT Major Item Trend Survey (2021.5)*; Software Policy Research Institute (2021[47]), *Software Industry Annual Report 2020*, https://spri.kr/posts/view/23366?code=annual_reports&s_year=&data_page=1.
B. Ministry of Science and ICT (2021[48]), *Software Export Statistics Survey (Annual) (2021.5), Software Export Statistics Survey (Monthly) (2021.5);* Software Policy Research Institute (2021[47]), *Software Industry Annual Report 2020*, https://spri.kr/posts/view/23366?code=annual_reports&s_year=&data_page=1.

In addition to the SW industry, the cultural industry has been growing in Korea. The contribution of cultural industries to GDP and employment in 2012 was only 2.4% and 2.6%, respectively, which is far lower than in most other OECD countries (OECD, 2014[49]). However, since the turn of the millennium, some creative industries in Korea have grown significantly. Following the initial success of Korean films and TV dramas in China and Japan, Korean music entertainment has become highly popular, particularly in East Asia and Southeast Asia. International interest in Korean cultural content has become frequently referred to by the term “Hallyu” (Box 3.6).

Box 3.6. The Hallyu phenomenon

Hallyu, which literally means “Korean wave”, was first used by the Ministry of Culture and Tourism in 1999 as a Chinese title for a music CD containing Korean content. It subsequently became an established term for Korean cultural products and content in China and Japan around the turn of the millennium and later in other countries as well. Hallyu has become a widely encompassing umbrella concept for global interest in Korean creative industries, covering broadcast programmes, film, music, performing arts, computer games, comics and webtoons, literature, fashion, food, tourism and beauty (KOFICE, 2020[50]).

Hallyu can initially be traced to the success of Korean movies and TV dramas in China in the late 1990s and in Japan in the early 2000s. These triggered a more general interest in Korean cultural content in neighbouring East Asian countries, where knowledge of Korea had been limited. In particular, Korean pop music entertainment (K-pop) became highly popular from the 2000s, particularly in China, Japan and Southeast Asia. In addition, some Korean online drama series have also become globally popular.

Hallyu has helped grow global interest in Korean culture at large, resulting in increased exports of Korean food and beauty products and an increase in foreign tourists visiting Korea. Hallyu has arguably also contributed to a more modern and positive image of Korea in other countries where negative associations related to the country’s 20th-century history, including poverty, war, dictatorship and political conflict, had previously been widespread.

Source: KOFICE (2020[50]), *2019 Hallyu White Paper*, https://kofice.or.kr/b20industry/b20_industry_00_view.asp?seq=1130.

K-pop has emerged as a major contributor to the global success of Korean cultural products and content. Additionally, the online game industry is another area where Korea has achieved notable success. Since around 2000, several newly established companies have published highly successful multiplayer online games, taking advantage of the rapid proliferation of broadband Internet in Korea. Some of these games have attracted and retained large player communities, leading to the growth of these companies. In fact, in 2019, 5 out of the 13 Korean “venture companies” with annual revenues of more than KRW 1 trillion were online game companies (Ministry of SMEs and Start-ups, 2021[22]). In the 2010s, games accounted for more than half of all exports of cultural products from Korea (Jin, 2016[51]). The broadcasting and film industries have also become major exporters, and similarly to music and online games, their largest markets are in East Asia and Southeast Asia (KOFICE, 2020[50]).

Governmental policies have supported creative industries mainly in two ways. First, following the enactment of the Basic Law for Promoting Cultural Industries in 1999, the government promoted the development and internationalisation of cultural industries through various specific support measures for the production and global distribution of cultural content (Jin, 2016[51]). Second, most companies that are active in creative industries qualify as venture companies, making them eligible for support measures available to such companies. In 2019, the Korean government identified cultural industries as a new major economic growth engine and formulated innovation strategies for these industries (Briefing, 2019[52]). As a result, specific programmes have been initiated to support different aspects of the creative industry business, including ideation, production, marketing and export (Lee, 2020[53]).

3.5. Korea's start-up system

In recent years, start-up activity in Korea has thrived, thanks in part to targeted and proactive government support. This section provides an overview of the Korean start-up ecosystem and its support system, followed by ongoing challenges that persist despite its strong growth. These challenges include issues related to internationalisation and diversity, as well as the need for comprehensive government support throughout all stages of business development.

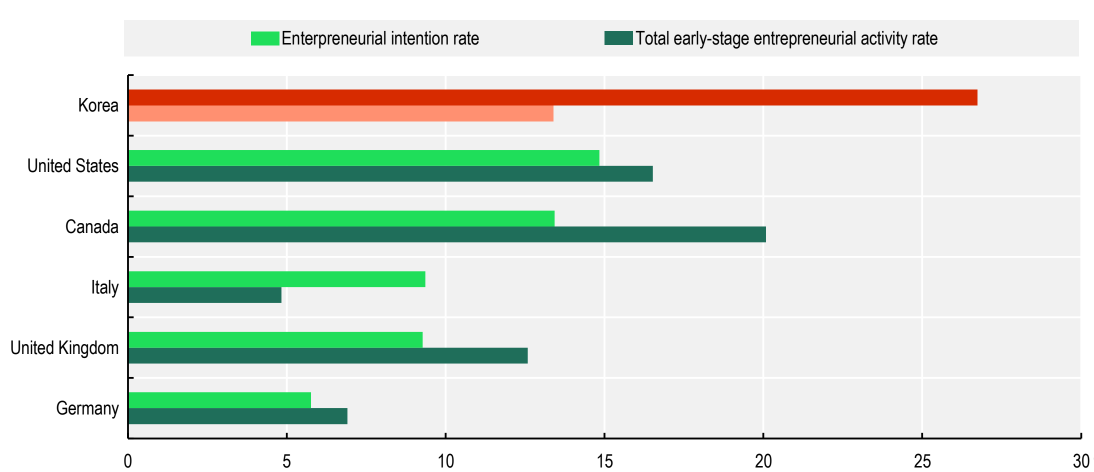
3.5.1. Korea is building a vibrant start-up ecosystem with a high level of entrepreneurial activity

Generally speaking, Korea has a high level of entrepreneurial activity compared with other developed countries. Large-scale surveys conducted by the Korea Institute of Startup and Entrepreneurship Development among adults aged 18-64 indicate that the intention to start a new business within the next three years is higher in Korea than in major Western countries, with 26.7% of respondents expressing such intentions in 2021. The proportion of nascent entrepreneurs in the process of setting up a new business is 13.4% in Korea, which is higher than in European countries and somewhat lower than in the United States and Canada (Figure 3.30). Additionally, the enterprise birth rate (calculated as the ratio of new enterprises founded in the last year to all existing enterprises) was 15.1% in 2017 for enterprises with employees, which is higher than in the United Kingdom (13.9%), France (11.4%), Italy (9.3%) and Germany (6.9%) (OECD, 2021[54]). In 2018 and 2019, 102 400 and 109 500 new companies were registered in Korea, respectively (STEPI, 2021[9]).

In Korea, the number of newly registered venture companies is a useful indicator for assessing and monitoring the development of start-up entrepreneurship. Under the Special Law to Promote Venture Capital Companies enacted in 1997, SMEs that receive significant investment by venture capital companies, are R&D intensive, or are primarily engaged in high-tech industries, can seek registration as venture companies and become eligible for privileges such as tax cuts. The total number of venture companies increased from 2 042 in 1998 to 36 503 in 2019 (Korea Venture Business Association, 2020[55]). Among all venture companies in 2019, 19.4% were engaged in the machinery, automotive and metal industries; 12.5% in the SW and IT service industries; 10.3% in the computer, semiconductor and electronic component industries; and 8.7% in the energy, chemical and precision industries.

Figure 3.30. Entrepreneurial activity in Korea and selected countries, 2021

Entrepreneurs as a percentage of adults aged 18-64



Source: Global Entrepreneurship Monitor (2022[59]), *GEM 2021/2022 Global Report: Opportunity Amid Disruption*, https://gemconsortium.org/report/gem-20212022-global-report-opportunity-amid-disruption.

3.5.2. Active government support has played an important role in creating a vibrant start-up ecosystem in Korea

In recent years, the promotion of entrepreneurship has become a top priority in Korea and has played a significant role in the growth of start-up entrepreneurship since the 2010s. The Ministry of SMEs and Start-ups co-ordinates national-level start-up support policies, with various other national government ministries also offering programmes. At the subnational level, the Seoul Municipal Government and provincial governments have their own start-up support policies. Governmental support policies for start-ups include direct investment, matching investment, R&D support and various indirect support programmes, such as entrepreneurship education, workspace provision, mentoring and consulting, and the organisation of networking events. In 2022 alone, the Korean government budgeted almost KRW 3.7 trillion (including loans) for start-up support programmes.

Many policy measures focus on providing financial support for start-ups, particularly for the commercialisation of technologies. This policy focus contrasts with the more indirect policy measures emphasised by other OECD countries where start-up ecosystems emerged earlier than in Korea, including Denmark, Germany, Israel, the Netherlands, Sweden, the United Kingdom and the United States. In these countries, policy focuses more on enhancing the general business environment for entrepreneurial activity and inter-regional and global connectivity, relying to a great extent on private actors (Brown and Mawson, 2019[56]).

3.5.3. Despite strong growth, start-up financing remains insufficient to support all stages of start-up development

In recent years, the conditions for financing and scaling up start-ups in Korea have greatly improved, although they differ significantly across different stages of start-up development. In the initiation stage, governmental seed finance support (mostly via small, non-repayable grants) is widely available. However, only around one-quarter of start-up entrepreneurs have been found to use these funding support programmes. Around half use personal funds, including funding from family and friends and loans from financial institutions to start their businesses (Hemmert and Kim, 2021[57]). In the scale-up stage, financing by angel investors (including angel investor associations) and venture capital firms has steeply increased. In 2019, KRW 4.28 trillion of venture capital was invested in Korea, up from KRW 2.08 trillion in 2015. Angel investment increased from KRW 96 billion in 2014 to KRW 554 billion in 2018 (STEPI, 2021[9]). However, the COVID-19 pandemic has significantly impacted financial support for start-ups. As new start-up activities contracted due to the COVID-19 outbreak, the growth rate of venture and growth capital was greatly reduced. While in 2018, venture and growth capital registered a growth rate of about 44%, in 2019, the growth rate was approximately 25%. In 2020, the growth in venture and growth capital registered a steep decline, with only 0.6% year-over-year growth (OECD, 2022[58]).

The increase in venture capital investment has been primarily driven by a government-financed fund-of-funds, the Korea Fund of Funds, operated by the Korea Venture Investment Corporation, with an accumulated capital of KRW 4.52 trillion by 2019. The Korea Fund of Funds enables the government to provide various financial support to start-ups, including the Tech Incubator Program for Startups (TIPS) (Box 3.7), recognised as one of the most successful government support programmes for start-ups. The critical factor contributing to its success is inviting private investors to select a technology entrepreneurship team and provide mentoring with the investment. The government provides R&D funding with matching investment, commercialisation and marketing support to ensure that technology start-ups survive “Death Valley”. Subsequent investments from domestic and foreign investors are actively made.

In addition to government-financed financial support for start-ups, the increase in angel investment has been enhanced by income-level tax exemptions introduced in 2018. The exemptions amount to 100% of investors' annual income up to KRW 30 million and 70% for income between KRW 30 million and KRW 50 million.

Box 3.7. Korea's TIPS program

The Tech Incubator Program for Startups (TIPS) was initiated in 2013 to expand funding opportunities for scaling start-ups in Korea. The programme was specifically designed to combine private and governmental funding. Promising start-ups are selected by accelerators, which invest KRW 100 million of venture or angel capital into them. This private equity investment is matched by up to KRW 1 200 million in government funding for R&D and other business expenses. Selected start-ups are also offered professional support by the accelerators that have invested in them. Successful start-ups are required to pay back 10% of the government grant as a royalty later (Korea Business Angels Association, 2021[59]). The government effectively outsources the selection of start-ups eligible for TIPS grants to accelerators, which need to be certified by the government to participate in the programme.

Many Korean start-ups have avoided government funding programmes due to the high perceived paperwork burden, including application and reporting requirements. The TIPS program reduces the administrative burden as accelerators help the start-ups they have selected navigate the administrative processes related to acquiring and operating government grants (Kyungjae, 2019[60]). Overall, the TIPS program is credited with substantially increasing funding opportunities for start-ups in Korea.

Source: Kyungjae, (2019[60]), "The reason why start-ups call TIPS 'Korea's mistake'"; Korea Business Angels Association (2021[59]), *Tech Incubator Program for Startups, About TIPS,* http://www.jointips.or.kr/global/.

In 2021, significant deregulation was introduced regarding private-led financial support for start-ups. Previously, Korean conglomerates were prohibited from investing in start-ups by establishing corporate venture capital (CVC) funds in order to protect investors and consumers by separating industrial and financial capital. However, the Korean government lifted this regulation in 2021, paving the way for the establishment of major venture capital funds by Korean conglomerates, with the aim of promoting collaboration between large companies and start-ups and increasing potential financial resources for start-ups. Despite this, some critics argue that the latest policy shift in CVCs is insufficient to tap into the full potential of CVCs by large companies, as some detailed restrictions are still in place. For instance, the ratio of funding by third-party investors (other than the companies setting up the CVCs) is limited to 40%.

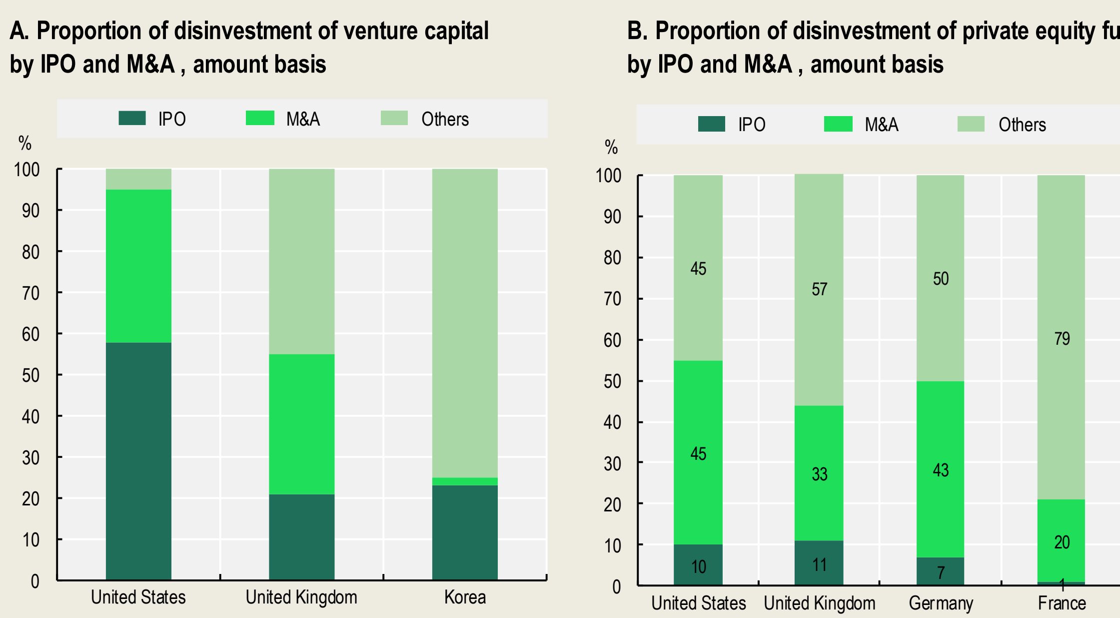
Exit models for start-ups in Korea have been relatively weak with respect to both initial public offerings (IPOs) and M&As. There were only 17 IPOs on KOSDAQ (Korea's main stock exchange) in 2019, down from 49 in 2015. The number of IPOs on KONEX (a separate stock exchange for SMEs) also decreased from 109 in 2015 to 97 in 2019. In addition, only 43 start-up M&As were recorded in 2019, a slight increase from 40 M&As in 2015 (STEPI, 2021[9]). It is estimated that recently, only approximately 30% of scaled-up Korean start-ups are achieving an exit via IPOs and 10% through M&As. An international comparison reveals weak exit models for start-ups in Korea (Box 3.8).

There have been some positive developments in this area, however. First, regulatory requirements for IPOs have been eased in recent years. Second, major domestic and foreign technology companies have shown increasing interest in strengthening their technological competencies by acquiring Korean start-ups. Nonetheless, some start-ups still face challenging exit conditions.

Box 3.8. International comparative study on the start-up ecosystem in Korea and selected countries

The Asan Nanum Foundation in Korea, a non-profit organisation established to promote entrepreneurship and strengthen the Korean start-up ecosystem, conducted an interesting study. Its report extensively analyses various indicators to assess the current status of the Korean start-up ecosystem in comparison with selected countries, including France, Germany, the United Kingdom and the United States. The indicators range from the creation of businesses to culture and perception, internationalisation and finance accessibility. The report specifically examines the financial accessibility in the exit phase for start-ups; some of the indicators used for this comparison are illustrated in Figure 3.31.

Figure 3.31. Comparison of IPOs and M&As in start-ups' exit phase (venture capital and private equity) in Korea and selected countries, 2021



Note: IPO: Initial public offering; M&A: Merger and acquisition.
Source: Asan Nanum Foundation (2021[61]), *International Comparative Study on Start-up Ecosystem (한국의 창업생태계 경쟁력 제고를 위한 국제 비교 연구)*.

3.5.4. Insufficient diversity and weak global connectedness could hinder Korea's start-up ecosystem from developing further

Despite the encouraging developments of the start-up ecosystem in Korea, there are also areas for improvement. This section highlights some of these areas, particularly from the perspective of diversity and global connectedness, which evidence from OECD countries has demonstrated to be essential for improving sustainable innovation for start-ups.

First, the diversity of founders and management teams in Korean start-ups is low in terms of the majors they have studied, their gender and their nationality (Born2Global Centre, 2021[62]; Hemmert and Kim, 2021[57]). Most start-up founders have an engineering background, while relatively few have studied other disciplines, such as economics, business, humanities and science. The observed ratio of female technology start-up founders across surveys ranges from 5% to 20%, with a large majority being male. Non-Korean founders are also very few, with one large-scale survey finding their ratio as low as 0.3% (Hemmert and Kim, 2021[57]). The low diversity of start-up founders and management teams is problematic, as diversity tends to enhance creativity and innovation (Østergaard, 2011[63]; Bouncken, Brem and Kraus, 2016[64]). This low proportion of foreign start-up founders is in stark contrast to leading Western start-up ecosystems, where approximately half of all start-up founders are immigrants (Migrants, 2020[65]). Although the Korean government started issuing visas for foreigners intending to establish technology start-ups from 2013, the number of visas issued in related categories has been low, and the impact of new measures remains to be seen ((STEPI, 2021[9])). In 2021, only 98 technology start-up visas (D-8-4) were granted to foreigners looking to start a business in Korea.

Second, relatively few Korean start-ups expand internationally, and even fewer succeed in doing so. In 2019, the ratio of newly founded firms in Korea that had expanded internationally stood at only 2.2% (STEPI, 2021[9]). This low internationalisation rate is in stark contrast to Europe, where around 20% of all recently founded firms have been classified as “born globals”, meaning they internationalise from the outset or soon after their establishment (Knight and Liesch, 2016[66]). Korean technology start-ups internationalise more frequently than newly founded firms in general, with an observed international expansion ratio of 26%. However, approximately half of these internationalised firms have an international sales ratio that does not exceed 10% (Hemmert and Kim, 2021[57]). While many Korean start-ups are interested in expanding their business to foreign countries, a perceived lack of knowledge or resources often prevents them from doing so. Others retreat from international markets after having entered them, as they find the hurdles to developing internationally profitable business models too high. Many start-ups lack international market knowledge because they do not have any non-Korean members in their management teams. Since their initial business models tend to be developed with a view to the Korean market, they often struggle to adapt later to foreign customer preferences or regulations.

3.6. Concluding remarks

Korea needs to address a number of imbalances in business R&D and innovation performance and respond to a number of challenges if it wishes to improve productivity performance and seize the opportunities from the digital and green transitions. Despite efforts to promote innovation more broadly in the economy, there remains ample room to further improve innovation in SMEs and high-value-added service sectors. In addition, further investment in emerging and converging technologies that will be the new drivers of productivity and growth will be necessary. In this context, connecting the Korean business innovation system to global innovation networks in terms of R&D and talent will be important. Finally, public policies to support business innovation should continue to be assessed for impact and improved without creating excessive policy uncertainty, which limits business uptake and efficient use of public support instruments. Table 3.10 summarises the main achievements and challenges facing business innovation in Korea going forward and is the basis for the recommendations contained in the overall assessment and recommendations (OAR) chapter.

Table 3.10. Korea's main achievements and challenges related to its business innovation

Achievements	Challenges
• Korea has seen rapid growth in its business sector R&D and shows top-notch business R&D spending among OECD countries.	• Korea's total ratio of innovating firms is the lowest among OECD countries.
• Korea has the world's second-highest number of ICT patent filings and the third-highest biotechnology patent filings.	• Korea relies significantly on R&D (vsthan non R&D) and in-house R&D rather (than collaboration)
• Korea has seen a significant increase in value-added, localising the value chain of its knowledge-intensive manufacturing industry.	• Many firms in Korea are still focusing on incremental innovation rather than disruptive innovation.
• Korea's global market share in high-tech industries, such as computers and pharmaceuticals, is increasing.	• Korea still lacks internationalisation of business R&D and innovation (e.g. co-patenting).
• Korea provides the largest total government support to business R&D as a percentage of GDP.	• There is fragmented public support for business R&D in Korea, with potential loss of efficiency and effectiveness.
• World-leading multinational firms in Korea have driven a significant increase in R&D expenditure (resulting in high concentration).	• The disparity in innovation between large and small firms is more acute in Korea than in other countries.
• Korea ranks at the top in ICT value-added, share of ICT sector employment and share of patents in ICT.	• The widening discrepancy, such as R&D and productivity between ICT and non-ICT industries, is of concern.
• Korea is building a vibrant start-up ecosystem with a high level of entrepreneurial activity (especially in Seoul).	• Exit models for start-ups have been relatively weak in Korea regarding both IPOs and M&As.
• Korea's government is actively and strongly committed to supporting start-ups (e.g. fund-of-funds, deregulation for CVC).	• There is Insufficient diversity (e.g. gender, nationality) and weak global connectedness in Korea's start-up ecosystem.
• Korea has seen impressive growth in its biotech industry, backed by a rapid increase in biotech patents and start-up creation.	• There is insufficient support for large-scale clinical trials and immature industry-academia-hospitals collaboration in Korea.
• Korea's government strongly supports promoting its service industry, e.g. by levelling its support to the service sector with manufacturing and introducing a regulatory sandbox.	• Service firms are still lagging in R&D investment in Korea, resulting in discrepancies in productivity and wages between the manufacturing and service industries.

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Notes

1. The RTA is defined as a country's share of patents in a particular technology field divided by the country's share in all patent fields. The index is equal to 0 when the country holds no patents in a given sector; is equal to 1 when the country's share in the sector equals its share in all fields (no specialisation); and above 1 when a positive specialisation is observed.

2. For further information, see https://www.wipo.int/export/sites/www/ipstats/en/docs/wipo_ipc_technology.pdf.

3. While there is no clear-cut definition of creative industries, they are broadly understood as economic activities concerned with the generation or exploitation of cultural or creative content, such as advertising, animation, architecture, design, film production, gaming, gastronomy, music, performing arts, software and interactive games, and television and radio (OECD, 2014).

4. As of the end of 2022, Korea had embraced six different areas for the adoption of the regulatory sandbox. These included: ICT and industrial convergence; financial innovation; regulation-free zone; smart city development; and R&D industrial cluster.

4 Production, circulation and use of knowledge for a new era of innovation in Korea

This chapter provides an overview of the research and development performance of Korea's higher education institutions (HEIs) and public research institutes (PRIs). Following an introduction of different bodies constituting the HEI and PRI system, the chapter explores different aspects of the HEIs and government research institutes. Finally, it investigates whether the missions, the funding structure and the governance system of each body support high-quality research and the reallocation of resources to new areas of economic and societal relevance.

The Korean research and education system receives worldwide recognition for its high expenditure on research and development (R&D) and for producing a high calibre of graduates, in particular in science-related fields. Despite having significant strengths in innovation inputs and outputs by some measures, the research system could be even more conducive to innovation by fully exploiting the potential which internationalisation has to offer. Research collaboration with foreign counterparts, as well as a diversification of the increasing influx of foreign students, have further room for growth. Diversity and collaboration across borders hold significant potential for new ideas and creativity and can instil entrepreneurial mindsets, thereby contributing to innovation. When it comes to research, there are few universities that dominate the academic landscape in terms of top-quality scientific outputs and collaboration with industry and international partners.

This chapter presents the overall research and innovation performance of Korea's National Innovation System by addressing the inputs and outputs of research and innovation. Subsequently, it discusses international research collaboration and student mobility, the performance of Korean universities as measured by rankings and a more detailed overview of quality and quantity produced per higher education institution (HEI). Finally, the first section explains the extent to which skills in Korea correspond to the demands of the 21st century and the digital transformation. Second, the chapter reviews the framework of the different types of HEIs and public research institutes (PRIs) by giving an overview of their respective mission, funding structure and the governance framework they are subject to. Third, this chapter elaborates on linkages among these institutions and with the private sector. Finally, the last section synthesises the main achievements and challenges in improving Korea's research system.

In order to obtain a comprehensive understanding of the Korean research and education system, this chapter has given particular consideration to the different contexts and roles of the major research-producing organisations, namely higher education institutions and research institutes. The main findings and recommendations of this chapter are as follows.

First, Korea's research system looks back on a rather unique trajectory as the concept of academic institutions performing activities other than teaching and establishing themselves as research-intensive institutions is comparatively recent. To increase resilience and impactful research being done by universities, the government should seek to strengthen their autonomy, for instance, through long-term funding. When considering the underlying funding structures of research institutes, it becomes apparent that a traditional focus on project-based funding may have contributed to short-term priorities over long-term impact. The government has recognised the need for easing funding rules and increasing autonomy for universities as well as adjusting the evaluation framework for research institutes, but it is still early to see the full effect of recent policy action.

Second, a cornerstone of disruptive innovation is high-risk research, which holds the potential to bring high rewards and transformative research, which could be strengthened at both Korean universities and research institutes. Diversifying the funding landscape and introducing a portfolio management approach could be effective policy measures in this regard.

Thirdly, linkages and scientific collaboration between higher education institutions and research institutes have the potential for further growth. Most collaboration between academia and industry takes place with SMEs driven by large government subsidies, while co-operation with chaebols is less evident. Creating proper incentives and governance arrangements by making collaboration an official mission of universities and GRIs is important. Encouraging young researchers to go abroad, and making better use of returning post-docs' international networks, are two measures that could help encourage cross-border co-operation in research.

4.1. Korea's research and innovation performance

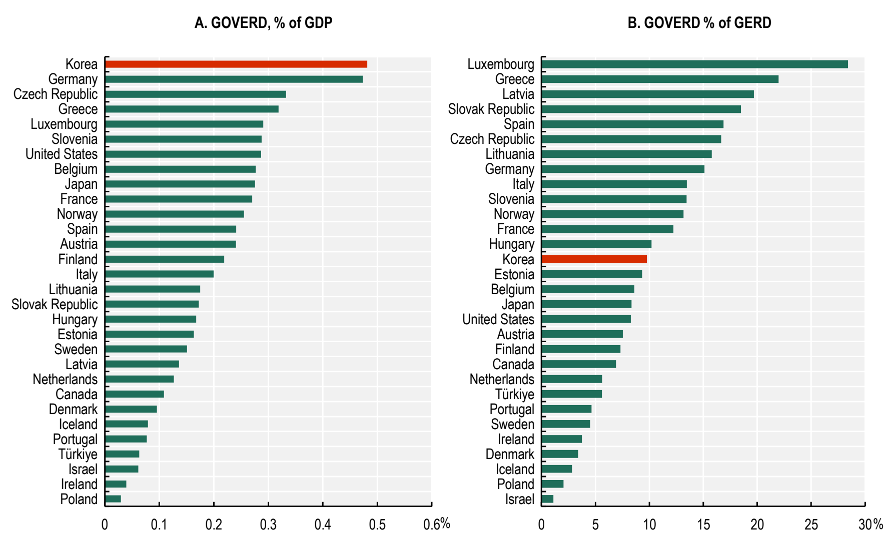
4.1.1. Although innovation inputs are strong, outputs remain average

Among OECD countries, Korea stands out for its high government expenditure on research and development (GOVERD) as a percentage of gross domestic product (GDP) with close to 0.5% in 2021 (Figure 4.1) (see also Chapter 2). However, when measured as a fraction of gross expenditure on research and development (GERD), GOVERD accounted for 9.8% in 2021, close to the OECD average. This indicator includes expenditures incurred by government units, such as PRIs, including government research institutes (GRIs), which are relevant to Korea's research system, as outlined later in this chapter.[1]

Korean higher education expenditure on research and development (HERD) in 2021 is on par at 38%, slightly lower than the OECD average (46%) (Figure 4.2, Panel A). Despite the fact that, unlike the practice in most OECD countries, Korean universities do not receive general university funding for their research activities, most higher education spending on research and development (HERD) in Korea is funded by the government, amounting to close to 80% in 2021 (Figure 4.2, Panel B), followed by the business sector at 13.8%. A relatively low share comes from the higher education sector itself as well as private non-profit (PNP) funding, at 6%, significantly less than Japan (45%), the United States (36.9%) (see Box 4.1) and France (15.3%). In addition, funding from abroad is the third lowest, at 0.56%, after Mexico (0.21%) and Japan (0.13%).

Figure 4.1. Government expenditure on R&D in Korea and selected countries, 2021

As a percentage of GDP and percentage of GERD



Note: GERD: Gross expenditure on research and development. Provisional data
Source: OECD *Main Science and Technology Indicators* (database), oe.cd/msti, June 2023.

Box 4.1. Higher education funding for R&D in Japan and the United States

Japan

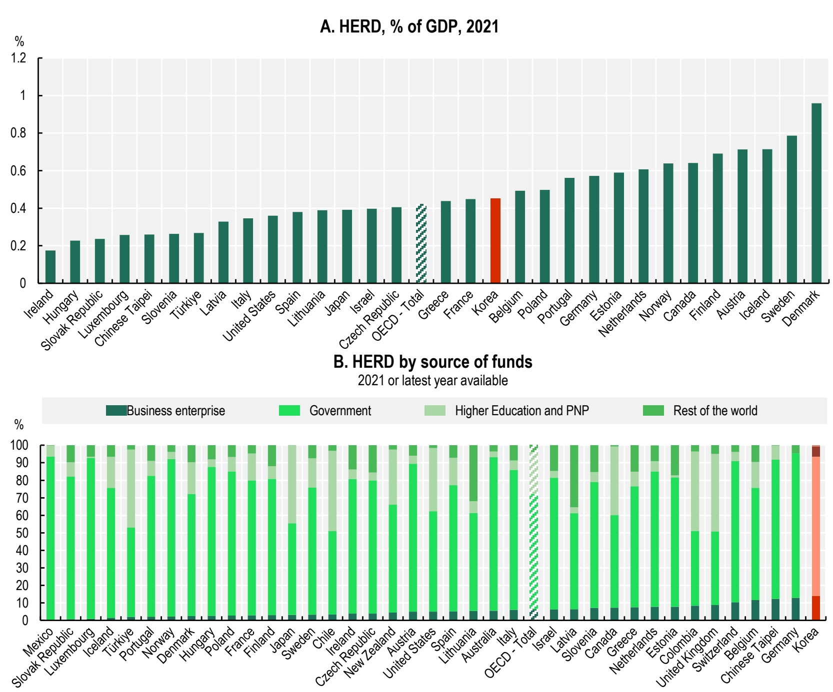
Most Japanese universities are private institutions (72%) that need to raise their own funding for research and development (R&D), notably through partnerships with the private sector. Until recently, the government has only provided grants to national universities to expand their postdoctoral programmes. In 2022, however, the government earmarked around USD 95 billion over time towards a university endowment fund, which, if fully realised, would constitute one of the world's largest endowment funds supporting scientific research.

United States

The federal government is the largest funding source for academic R&D funding at US universities, with about 53% or around USD 42 billion in 2018. The second-most important source (USD 21 billion in the same year) is the academic institutions themselves, many of which preside over large endowments, which include thousands of philanthropic donations to support scientific research. Non-profit organisations and the business sector are also significant sources of academic funding, albeit to a lesser extent, with USD 5.4 billion and USD 4.7 billion, respectively, in 2018.

Source: (American Council on Education, 2022[1]); *US-Japan Higher Education Engagement Study*, https://www.acenet.edu/Documents/USJP-HEES-Findings-Research-FactSheet.pdf; (National Science Foundation, 2022[2]). *Academic R&D in the United States*, https://ncses.nsf.gov/pubs/nsb20202/academic-r-d-in-the-united-states.

Figure 4.2. Higher education expenditure on R&D



Note: PNP: Private non-profit. Funding from abroad corresponds to the rest of the world. Provisional data.
Source: OECD *Main Science and Technology Indicators* (database), oe.cd/msti, April 2023; OECD *Research and Development Statistics (RDS)* (database), oe.cd/rds, June 2023.

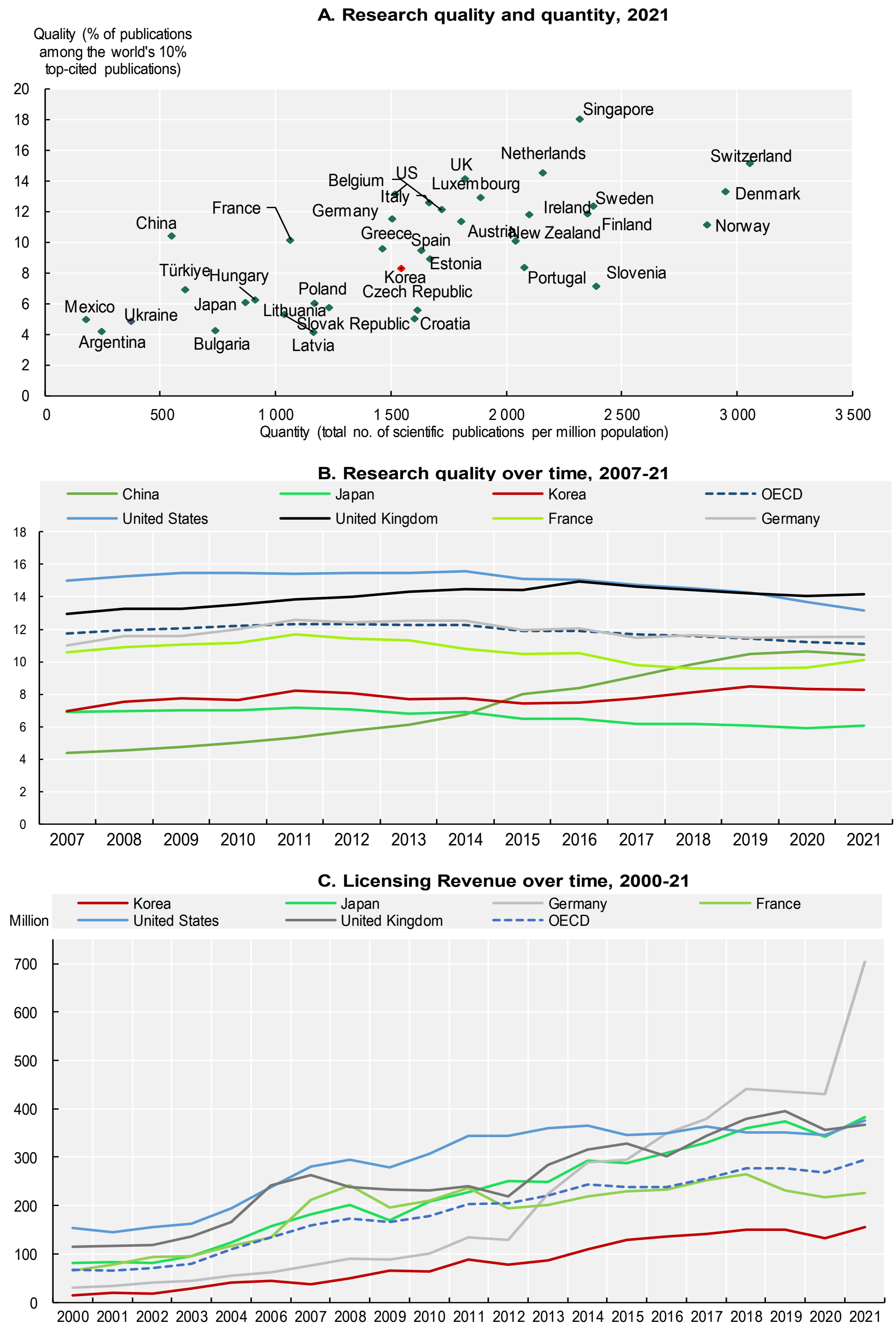
Despite leading gross expenditure on R&D (see Chapter 2), Korea's research performance, as measured by the share of scientific publications among the world's 10% top-cited, lags behind many leading OECD countries and other economies, such as Singapore; its share is at 8% below the world average (Figure 4.3, Panel A).

However, Korean research performance fares considerably better when considering the 1% top-cited publications, as some databases do, such as the UK Department for Business, Energy and Industrial Strategy's database. It shows that in 1996, Korea had a share of 0.4% of the world's 1% top-cited publications. Since then, it has increased almost sevenfold to 2.7% in 2020 (Department of Business, Energy and Industrial Strategy, 2022[3]). The discrepancy in performance between the 1% and 10% top-cited publications may indicate a vast performance gap between a few top-performing universities and the rest, lagging significantly. Intellectual property (IP) revenues are significantly lower than those of leading OECD countries, which is only about half the OECD average (Figure 4.3, Panel C). Moreover, these revenues have been stagnating, and interviews with stakeholders indicated it is expected that the contribution of start-ups founded by university researchers, notably professors, to universities' revenues, albeit still relatively small, will grow in importance, as opposed to revenues from licensing technology to companies.

Overall, it is difficult to measure industry-academia collaboration. Several indicators should be considered, including the number of co-publications, number of patents, number of copyright licences, technology transfer revenues and various metrics concerning spin-offs and joint ventures (Seppo and Lilles, 2012[5]). However, such data are rarely collected on a systematic basis. A proxy often used is the indicator of industry-academic co-publications, even though most industry-academia collaboration projects do not result in co-publications. Pohl finds that while such co-publications stagnate worldwide at about 2.8% of all publications,[2] their field-weighted citation impact (FWCI) is 1.70, meaning that co-publications have an impact of 70% higher than that of all publications. This effect is much higher still for Korea, where industry-academia co-publications reach an FWCI of 3.50. Sungkyunkwan University is quoted among the top-ten academic actors in industry-academic co-publications globally, where such co-publications represent 16% of all publications.[3] It focuses mostly on medical and natural sciences (biological sciences, mathematics, chemistry, physics) and has a balanced portfolio of corporate partners, with half of its top-ten partners from Korea and another half from foreign countries. Samsung figures among the top-ten global corporate players in academia-industry co-publications, with 82% of its publications being in collaboration with academia; all of the top-ten academic partners are Korean (Pohl, 2021[6]). The global leadership role of Samsung in its fields of focus may explain the high citation impact of industry-academia co-publications. Nevertheless, industry-academic co-publications are declining in Korea, unlike most other leading OECD countries, for which the trend is stagnant or slightly increasing (Figure 4.4).

Kang et al. (2019) studied patenting behaviour in the electric vehicle domain. They found a strong concentration on the corporate side, with Hyundai Motors in the lead and significant contributions from LG Electronics and LSIS Co. On the academic side, the leading actor is the Korea Advanced Institute of Science and Technology (KAIST), followed by Kookmin University and Korean Aerospace University (Kang et al., 2019[7]). In Chapter 3, it was shown that in Korea, international co-operation in patenting is particularly low in all three categories, i.e. the percentage of patents owned by foreign residents, invented abroad and with foreign co-inventors. Similarly, co-inventions with other countries are significantly lower than the OECD average and also than the share in benchmarking countries, such as Japan and the People's Republic of China (hereafter, "China") (Figure 4.5).

Figure 4.3. Research quality and quantity (2021), research quality over time (2007-21) and revenue from intellectual property (2000-21) in Korea and selected countries



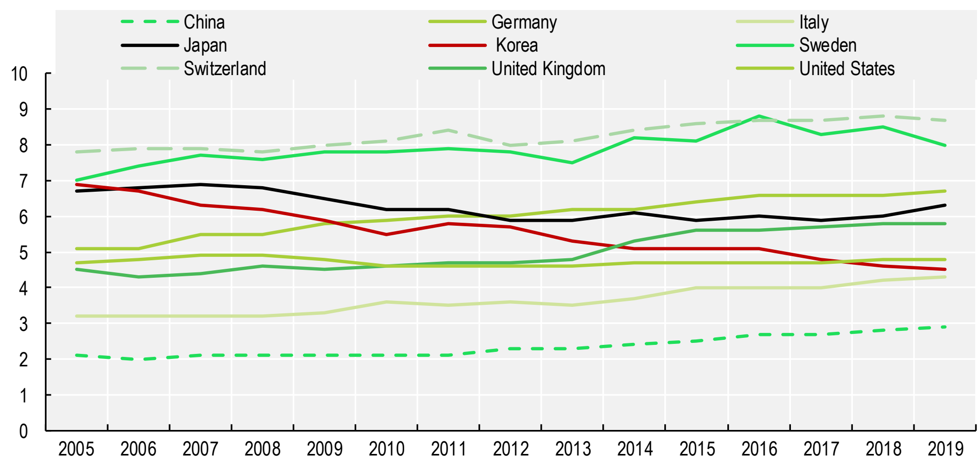
Note: Charges for the use of intellectual property includes revenues from patents, trademarks, copyrights, and industrial processes for the economy as a whole from the private and public sector.

Source: Panels A and B: OECD calculations based on *Scopus Custom Data*, Version 6.2022, September 2022; (SCImago Journal Rankings, 2022[4]).

Panel C: OECD calculations based on IMF Balance of Payments Statistics Yearbook data and OECD Labour Force Statistics, oe.cd/il/54K, June 2022.

Figure 4.4. Share of academic-corporate co-publications in Korea and selected countries, 2005-19

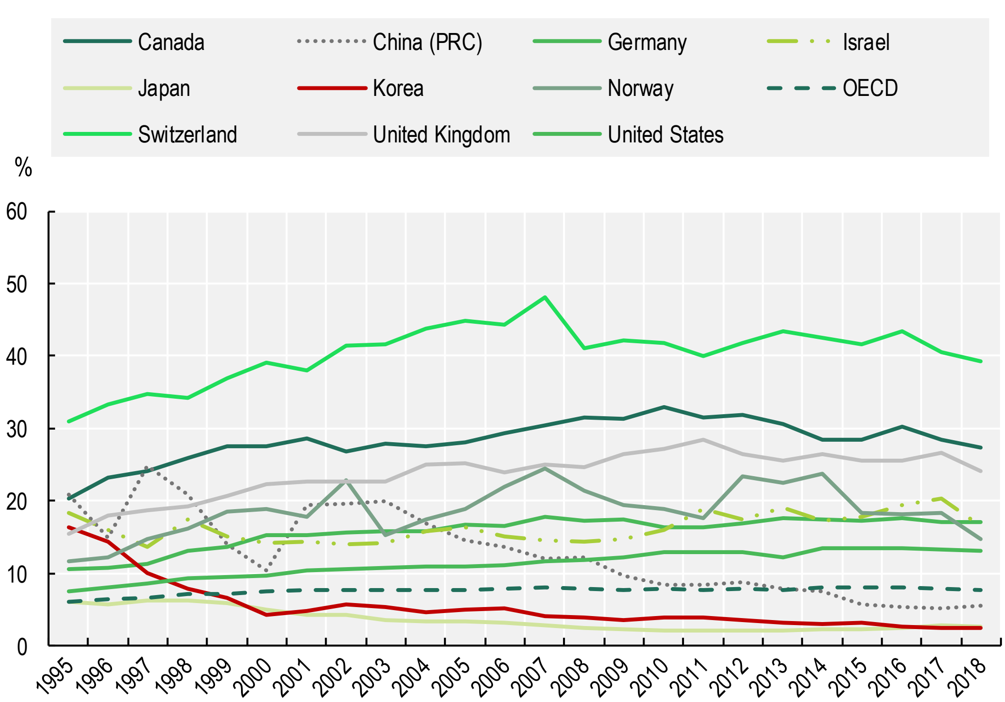
As a percentage of total publications



Source: Elsevier (2021[8]), *Scopus Custom Data*, Version 5, May 2022.

Figure 4.5. International co-inventions

As a share of total domestic patent inventions

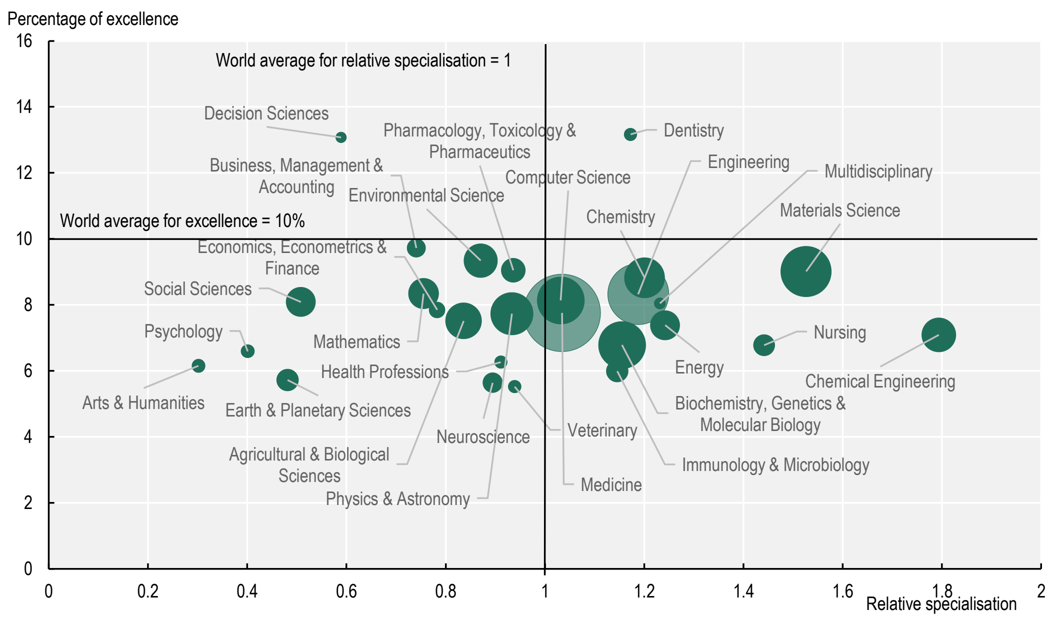


Note: As measured by patent applications filed under the Patent Cooperation Treaty. Co-inventions refer to the share of patents with at least one inventor located abroad as a share of total patents developed domestically.
Source: OECD (2022[9]), *Patent Statistics* (database), oe.cd/4Fj, August 2022.

Examining research performance by field (Figure 4.6), it becomes apparent that in most fields, the percentage of 10% top-cited publications is below 10%, which is by definition the world average, except for decision sciences and dentistry, which constitute a small share of total publications. Most publications are in medicine, engineering, materials and computer science, with relatively few publications in the social sciences, arts and humanities and business-related sciences. It is in these fields that Korean research has among the lowest relative specialisations, thus implying that these are not seen as priority subjects in research. Following Leach and Wilson (2010), the value of arts and humanities research lies in developing people's responsiveness to (societal) problems, to see failure not as a wasted opportunity but to acknowledge the possibility of reusing ideas and concepts over time. It also invokes a sense of freedom and space for experimentation, critical for creativity and innovation (Leach and Wilson, 2010[10]).

On the other hand, Korean research is highly specialised in the advanced fields of chemical engineering, materials sciences and, to a lesser extent, engineering, (bio)chemistry and energy, corresponding to the traditional strength of Korean conglomerates and the economy more broadly. Nevertheless, its relative specialisation in the more fundamental sciences of mathematics, physics and astronomy is lower than the world average.

Figure 4.6. Specialisation and citation impact in science, Korea, 2020



Note: Scientific publications are measured in fractional counts. Percentage of excellence is the share of 10% top-cited publications of total publications. Relative specialisation is the thematic occurrence in publications compared to the world average. A relative specialisation above 1 denotes a specialisation higher than the world's average. The bubble size indicates the number of publications.
Source: OECD calculations based on Scopus Custom Data, Elsevier, Version 5.2021, September 2021

4.1.2. International research collaboration has the potential to grow

International collaboration in research is traditionally a means to enhance the flow of ideas, accelerate the emergence of new concepts, and cross-fertilise scientific endeavours across scientific institutions and countries. It supports the generation of new knowledge, solves complex problems and enables innovative practices in public institutions, private enterprises and academia (Sergi, Parker and Zuckerman, 2014[11]). The COVID-19 pandemic has demonstrated the increased role of international collaboration in solving societal challenges, as the science and innovation response to the COVID-19 pandemic has been largely an international effort (OECD, 2021[12]).

Even so, international collaboration has experienced rapid growth, as international co-publications have evolved from 10% of all publications in 1996 to 21% in 2019. Shares of international co-publications vary, ranging from 8.4% in humanities to 23.5% in natural sciences and 24.9% in agricultural sciences (Pohl, 2021[6]). International collaboration has been shown to enhance citation impact over institutional collaboration by 49% in the United States and 70% in Europe (Science Europe and Elsevier's SciVal Analytics, 2013[13]). Pohl also finds that FWCI enhanced by 70% in Korea (Pohl, 2021[6]).

Korean involvement in intergovernmental institutions, international partnerships, bodies and fora

Korea has been a full member of the International Fusion Experimental Reactor (ITER) since 2003, based on its national experience with KSTAR (Korea Superconducting Tokamak Advanced Research). Korea supplies superconducting magnets, vacuum containers, and tritium transport and storage systems for the facility, bearing 9% of the total cost (ITER, 2022[14]).

Although Korea is not a member of CERN, the European Particle Physics Laboratory,[4] 45 teams from 29 Korean institutions participate in 17 experiments at CERN, the most significant being the Compact Muon Solenoid experiment (CMS), A Large Ion Collider Experiment (ALICE) at the Large Hadron Collider facility, and a theoretical physics exchange programme, governed under the International Co-operation Agreement signed in 2006 (CERN, 2022[15]). CMS is one of the largest international research collaborations that ever existed, with 5 500 participants (scientists, engineers and support staff) representing 241 scientific institutions from 54 countries worldwide (CERN, 2022[16]). Korea established computing centres for these flagship experiments.

Korea has a longstanding collaboration with the European Union under the 2007 Agreement on Scientific and Technological Co-operation between the European Community and the Government of Korea and Decision 2007/241/EC, establishing a formal co-operation framework. The collaboration has resulted in more than 130 joint research projects since 2007, including 82 projects under Horizon2020 (Korea-EU Research Centre, 2022[17]). As of 2017, the success rate of Korean applicants (25.7%) was higher than that of their international counterparts (14.7% overall) (Chung and Lee, 2019[18]). In addition, the 2006 agreement between Euratom and Korea defines the framework for collaboration in fusion energy research. Furthermore, exploratory discussions are underway on the association of Korea to Horizon Europe following Korea’s expression of interest dated 14 February 2022.[5] An association would bring the collaboration to a higher level. Furthermore, as announced in June 2022, Korea has become a full member of Eureka, the world’s largest R&D platform, as the first country in Asia (Ministry of Trade, Industry and Energy, 2022[19]).

While Korea has extensive co-operations in other major international research infrastructures, it currently has no formal co-operation with the European Molecular Biology Laboratory (EMBL), which could offer the opportunity to increase international co-operation in the biological sciences. Although primarily a European organisation, EMBL is open to partnerships, as evidenced by the Associate Membership status of Australia, with a network of seven Australian universities forming an EMBL Partnership Laboratory.[6] Korea is also not a member of the International Space Station, even though a possible Korean membership was mentioned in 2010 by the Head of the European Space Agency, Jean-Jacques Dourdain (de Selding, 2010[20]).

In 2019, the Korean Ministry of Science and ICT (MSIT) signed a Memorandum of Understanding (MOU) with the Science and Technology Directorate of the US Department of Homeland Security to deepen bilateral co-operation in science and technology (S&T) R&D with regard to a variety of issues, including disaster relief, public safety and infectious diseases. The partnership is envisioned to identify mutual challenges as well as shared opportunities and priorities and, therefore, the most efficient areas of investments in technology. Furthermore, the co-operation entails joint research, researcher exchanges, and conferences between the two countries' research institutes, academic institutions, and R&D-related public agencies. It therefore promotes contact and linkages between S&T institutions, including academia, government, science academies, national centres for S&T research and funding bodies. The agency-to-agency agreement is the first step toward the eventual objective of establishing a government-to-government agreement (Department of Homeland Security, 2019[21]).

Korea and Japan have more productive and stronger-growing research co-operation with China than with each other. This is because research collaboration between Korea and Japan tends to occur based on personal relationships rather than through large-scale government-led initiatives. For instance, Seoul National University (SNU) set up a new laboratory of the University of Tokyo's Institute of Solid State Physics and the Center for Correlated Electrons at the Institute of Basic Science in Korea, initiated by Se-Jung Oh, the President of SNU and Korea's Institute of Basic Science. Researchers tend to remain in their research institutes and do not change jobs regularly, which has been conducive to establishing impactful long-term relationships. Furthermore, the export of equipment between the two countries is relatively simple compared with China, where these are subject to strict controls (Fuyuno, 2021[22]).

The Korean Academy of Science and Technology (KAST), the Korean Social Science Research Council (KOSSREC) and the National Academy of Sciences of the Republic of Korea (NAS) are members of the International Science Council.

Large Korean firms with strong global market presence also create and acquire R&D centres internationally. Such centres pursue two types of strategies: acquisition of new technology and "localisation" of production, i.e. adaptation to local consumer needs and tastes. Examples include the following:

- The LG Zenith Lab in Lincolnshire, Illinois, United States, resulted from an acquisition of Zenith, a US company, which enabled LG to enter the digital TV industry during the 1990s. Another centre for electric vehicle components was set up in Troy, Michigan, United States. In connected car solutions, LG teamed up with Qualcomm in 2017 to develop a range of next-generation car solutions.
- R&D centres for local adaptation exist in India (LGEIL), Beijing, China and northern France for adaptation to European consumers (Ramaswamy, 2007[23]).
- Samsung Electronics set up 16 R&D centres in 14 countries, with 7 centres focused on artificial intelligence (AI) in Korea, the United States, the United Kingdom and Canada, among others (Samsung Electronics, 2022[24]).
- LG Electronics partnered with the University of Toronto and set up an AI lab focusing on neural networks for deep learning (University of Toronto, 2018[25]). Of a total of about 20 000 workers in its R&D operations, roughly one-quarter are foreigners. Nevertheless, according to the project team interviews, the integration of foreigners into Korean companies is still a cultural challenge.
- SK Hynix established Gauss Labs, an AI company financed with USD 55 million (Jung, 2020[26]).

Government initiatives for internationalisation

The International Co-operation Programme in S&T is a group of programmes funded by the MSIT and operated by the National Research Foundation (NRF) since 2009. Its objectives are to strengthen institutional infrastructure for international co-operation in science, technology and innovation (STI); support Korean universities' co-operation with their foreign counterparts; attract excellent overseas research institutes; promote global R&D co-operation and networking; and support developing countries through S&T-focused overseas development assistance (ODA) projects. Its main components are researcher exchanges, joint research projects, ODA, and co-operation centre support programmes.[7]

The MSIT operates Korea Innovation Centres (KICs) in Silicon Valley (KIC Silicon Valley), Washington, DC (KIC Washington), Berlin (KIC Europe) and Beijing (KIC China) to provide step-by-step accelerating programmes for Korean start-ups and small and medium-sized enterprises (SMEs) to expand their business in global markets (https://www.kicsv.org/). In addition, the India Korea Center for Research and Innovation (IKCRI) was established in 2020 to do joint research on digital transformation, future manufacturing, future utilities and healthcare. Eight "K-startup centres" have been established across European countries, Asia and the United States to act as a globalisation support platform for start-ups.

The Korea Institute for Advancement of Technology (KIAT) has an international technology co-operation division,[8] which has diverse international collaboration programmes, including joint R&D on quantum technologies, with most advanced OECD countries as well as India and China, multilateral joint R&D projects, including Eureka, Eurostar 3, Horizon Europe and M-ERA-NET, and Korea-Association of Southeast Asian Nations (ASEAN) technical co-operation. It also runs a number of international centres in the United States, Europe and Asia, a bilateral programme with France, and industrial technology ODA support.

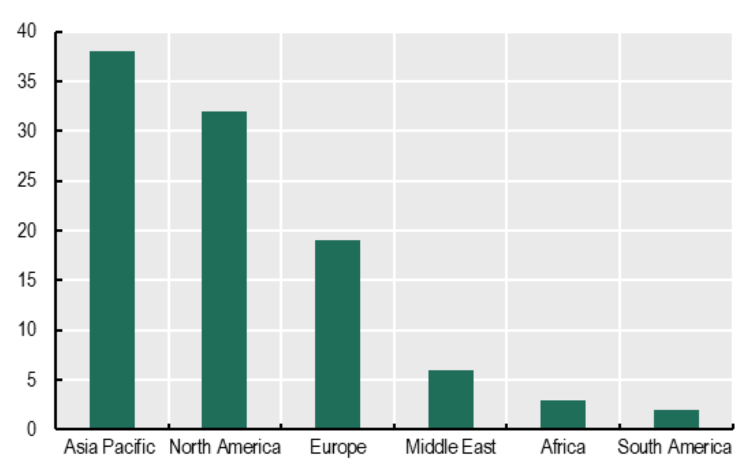
International co-publications

Between 2018 and 2020, Korea had 81 000 international co-publications (i.e. co-authored publications with at least one author having an institutional address/affiliation outside Korea). In terms of regional distribution, the Asia-Pacific region accounted for the largest share of total co-publications (38%), followed by North America (32%) and Europe (19%) (Figure 4.7). Looking at individual countries, the United States is by far Korea's most important research partner, measured in terms of co-authored publications, with 33 600 joint publications between 2018 and 2020, followed by China (15 600 co-publications), Japan and India with 8 600 and 8 200 co-publications, respectively. Among the top 20 countries with which Korea has the most co-authored publications, between 2018 and 2020, Korean co-publications increased by far the fastest with Viet Nam, followed by Saudi Arabia, China and Pakistan (Table 4.1).

Compared to other OECD countries with significant research expenditures, Korea has relatively few international co-publications, both as a share of total publications and in relation to the size of its population (Figure 4.8). For example, countries such as Australia, Costa Rica, France, Germany, Italy, New Zealand, Sweden, Switzerland and the United Kingdom had more than twice as many internationally co-authored publications per capita than Korea, while Japan and China had fewer.

Figure 4.7. Korea's co-publications with selected regions, 2018-20

Percentage of total co-publications



Note: All publication types. Fractional counts.
Source: Elsevier, *Scival Data*, SciVal, October 2021.

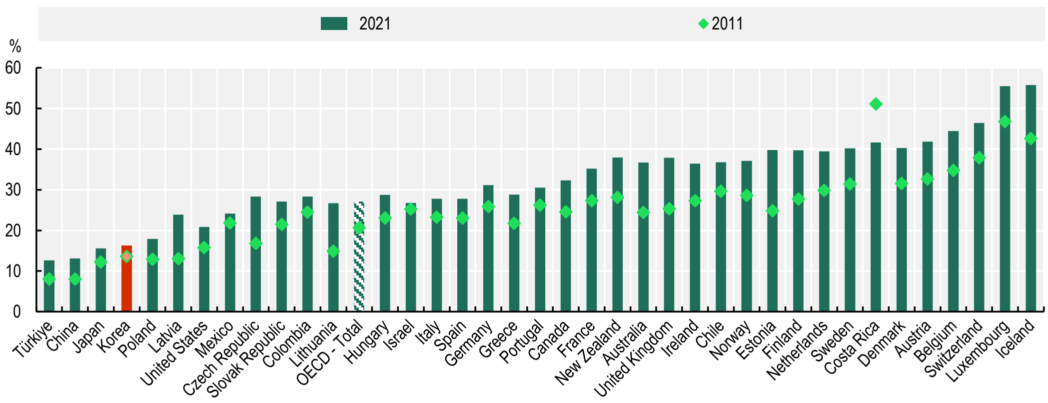
Table 4.1. Korea's co-publications with selected economies, 2018-20

	Top research collaboration partners	Number of co-publications	Increase (%)
1	United States	33 475	7.1
2	China	15 632	37.6
3	Japan	8 552	6.7
4	India	8 186	27.3
5	United Kingdom	7 056	23.3
6	Germany	6 343	16.3
7	Australia	4 908	28.3
8	Canada	4 193	33.5
9	France	4 035	15.7
10	Italy	3 964	33.5
11	Pakistan	3 745	36.3
12	Viet Nam	3 271	104.5
13	Spain	3 046	27.4
14	Chinese Taipei	2 985	9.5
15	Switzerland	2 500	21.2
16	Singapore	2 292	33.7
17	Saudi Arabia	2 289	52.7
18	Islamic Republic of Iran	2 045	31.9
19	Netherlands	2 030	24.4

Note: All publication types.
Source: Elsevier, *Scival Data*, SciVal, October 2021.

Examining internationally co-authored papers as a share of total publications, international research collaboration has increased for many OECD countries in the past decade (Figure 4.8). In the case of Korea, international co-publications accounted for a significantly smaller amount of the country's total publications in 2009, with less than 14%, increasing to about 16% in 2019. In comparison, France, Germany and the United Kingdom had a higher share of co-publications in 2009, 27%, 26% and 25%, respectively, and their shares increased to 36% for France and the United Kingdom and 31% for Germany in 2019. China, which had significantly lower shares of internationally co-authored papers compared to Korea in 2009, saw its shares increase more quickly, with a growth rate of 76% during the period compared to 16% in Korea. Between 2009 and 2019, the number of internationally co-authored publications in Korea grew more quickly than in France, Germany, Japan, Switzerland, the United Kingdom and the United States. This indicates that while international research collaboration has increased in absolute terms, the increase has not exceeded the simultaneous growth in total research output to the same extent as it has done for the other countries examined.

Figure 4.8. Percentage of total scientific publications involving international collaboration



Note: International collaboration refers to publications co-authored among institutions in different countries. Estimates are computed for each country by counting documents for which the listed affiliations include at least one address within the country and one outside. Single-authored documents with multiple affiliations in different countries count as institutional international collaboration.
Source: OECD calculations based on Elsevier (2022[27]), *Scopus Custom Data*, Version 6.2022, September 2022.

In particular, given rising societal challenges, such as climate change, which are global and systemic in nature, with wide-ranging effects on economies, from agriculture to energy, the need for international co-operation is becoming greater. Priority setting in national agendas needs to address questions about what to fund and which requirements must be fulfilled. For instance, in the European Union, the Horizon 2020 programme sets out international collaboration as a requirement by stipulating that a project must involve participants from at least three member states and associate countries. As part of the 2021-27 funding programme (Horizon Europe), efforts to increase internationalisation have further been extended to include exceptional funding for participants from non-EU third countries to encourage topics that support internationalisation and the implementation of multilateral agreements. Furthermore, the funding channel provides a mechanism to incentivise long-term-oriented financial support for co-operative research addressing societal challenges. For this purpose, separate advisory groups have been established with industry, academia and civil society stakeholders to help implement related work programmes. It is worth noting that Korea is one of 20 countries with whom the European Union has entered into bilateral S&T agreements meant to strengthen policy dialogue with project-based and bottom-up co-operation (European Commission, 2022[10]; OECD, 2017[10]).

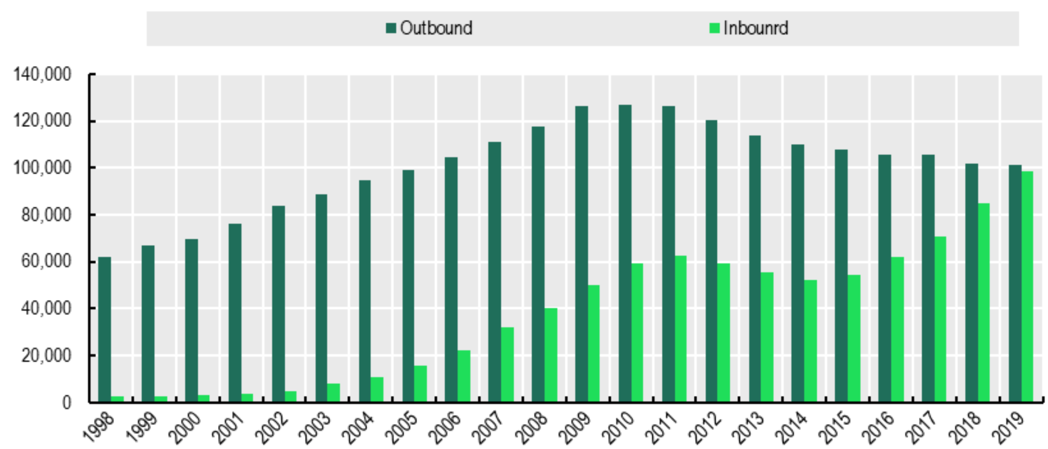
Furthermore, Macháček et al. show that Korean universities tend to recruit staff from within their institution more than in the United States, Australia, Canada, Germany, France and the Netherlands, but lower than Sweden, Japan, China, Spain or Italy. They also show that the degree of internal recruitment differs more widely among Korean institutions than in the other countries mentioned, with the exception of China, pointing to a less homogenous university system than in other countries (Macháček et al., 2021[28]). In addition, several stakeholder interviews confirmed that Korean researchers tend to be reluctant to partner with international researchers. This is because of administrative complexity, since obtaining project-based system (PBS) funding is relatively straightforward, which disincentivises taking on the additional burden of partnering with international researchers. As shown in Chapter 2, the international mobility of Korean researchers is among the lowest in the OECD.

4.1.3. International student mobility is growing, but integrating foreign students is a challenge

The number of international students at Korean universities increased more than tenfold between 2001 and 2019 and doubled between 2014 and 2019 (Jon and Yoo, 2021[29]). The increase is partially explained by the Study Korea Project (SKP) launched in 2005, which set clear goals for increasing the number of international students. Consequently, the share of international students at Korean universities has risen significantly, alongside a decline in Korean students (due to demographic changes) in the past decade. Launched in 2004, the SKP had the initial objective of 50 000 international students, which was expanded to 100 000 in 2008. This was expanded once more in the form of the Study Korea 2020 Project in 2013, which aimed to attract 200 000 students by 2020 (Green, 2015[30]). After 2015, the number of international students surged again, reaching nearly 100 000 in 2019 (Figure 4.9).[9] Nearly half of Korea's international students in 2019 came from China, followed by Viet Nam, which accounted for nearly a quarter (Jon and Yoo, 2021[29]). In 2015, the Korean Research Fellowship Programme was launched. It provides fellowships, postgraduate loans, and scholarships to outstanding overseas students to conduct research in emerging fields and thereby help them grow. While not necessarily impacting the number of foreign students coming to Korea, the programme is an important addition to attracting top talent. The ability to attract and retain foreign students is an important challenge and can be fostered by improving student satisfaction.

Figure 4.9. International student mobility in Korea, 1985-2019

Number of students



Note: Outbound students are internationally mobile tertiary students who study abroad. Inbound students are international tertiary students who leave their origin country to study in Korea.
Source: UNESCO (n.d.[31]), *UIS Statistics*, http://data.uis.unesco.org/, August 2022.

Some of the most significant factors besides academic quality that influence student satisfaction are the ability to speak the Korean language, cultural proximity to the students' origin destination and whether they receive financial support via scholarships. About one-third of students report not understanding the Korean language very well or at all, hindering their ability to communicate effectively (Alemu and Cordier, 2017[32]). This may explain why Korea tends to be a more popular choice for studying abroad among East Asian students who share cultural and historical ties and whose students are often more reliant on financial support.

While initiatives such as exchange programmes, including Campus Asia, AIMS and ASEM-DUO, have been introduced to attract international students, Moon (2016), in examining internationalisation and diversity in higher education in Korea, finds significant barriers to interaction and integration of foreign students once they are in the country related to language, social integration and cultural differences. Similarly, according to Lee and Bailey's (2020) mixed method analysis, overall interest in interacting with international students is low among Korean students. Language, mentoring, culture and social programmes to increase interaction are some measures that could help contribute to better integration of international students (Lee and Bailey, 2020[33]). Moon interprets the finding as a manifestation of a larger pattern of instrumentalisation of internationalisation and globalisation, where specific aspects of internationalisation are "cherry-picked" or appropriated to serve a national agenda. Similar mechanisms can be found to be at work in Japan and are also present in China's policy of opening up, which seeks to attract foreign technology and talent in selected fields in order to serve the country's catching-up agenda, with the ultimate aim of allowing China to isolate itself from the world if/when it chooses to do so. It should be pointed out that selectively pursuing certain aspects of internationalisation as a means to strengthen the nation-state can be found in many regions and countries, including Europe, Australia and North America (Moon, 2016[34]).

4.1.4. Korean university rankings could improve further

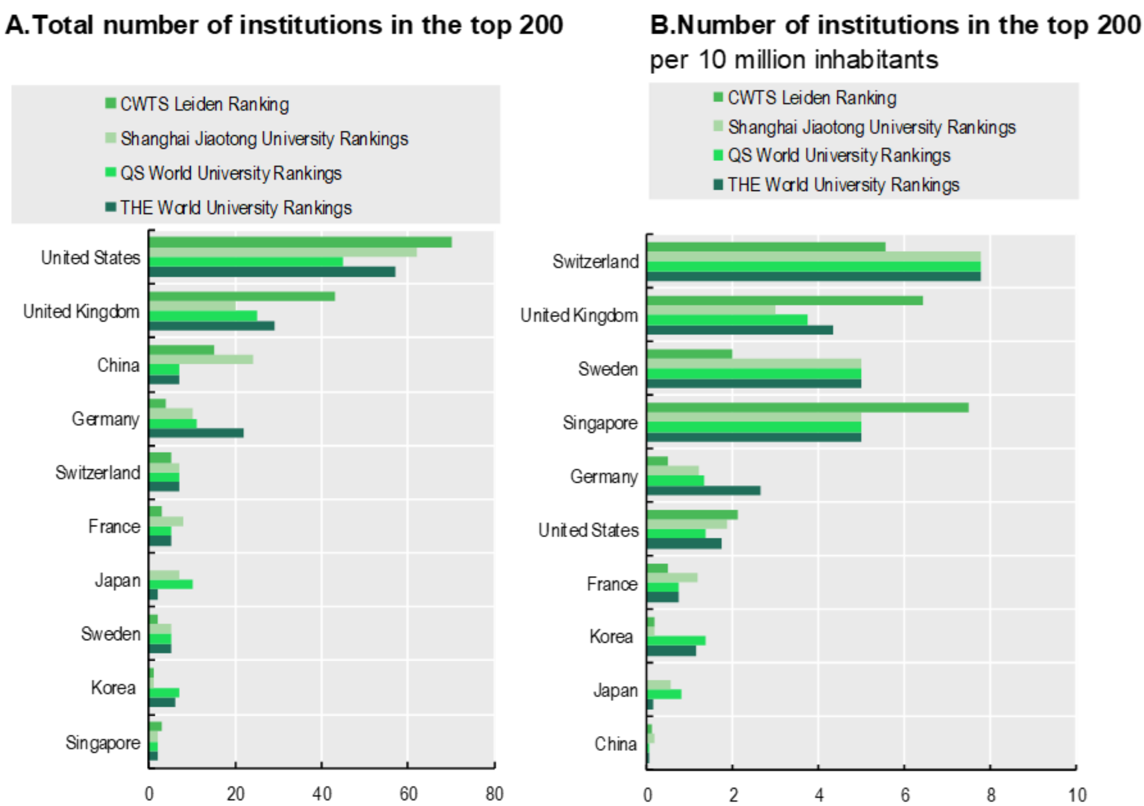
In the past decade, a handful of Korean universities have consistently been ranked among the top 200 in the world in the Times Higher Education World University Rankings and the QS World University Rankings, with SNU and KAIST quite regularly among the top 100. However, Korean universities, as a whole, score considerably lower in the Shanghai Jiaotong Ranking and the Centre for Science and Technology Studies (CWTS) Leiden Ranking, which, in comparison to the other two rankings, assign more weight to indicators for research excellence (e.g. Nobel Prizes and highly cited research in proportion to size) and less to reputation (as measured by surveys) or teaching quality (measured by surveys and student/teacher ratios) (Lim, 2018[35]). The CWTS Leiden Ranking, for example, ranks universities according to the top 10% cited publications as a percentage of total publications. According to the 2021 CWTS Leiden Ranking, only the Ulsan National Institute of Science and Technology (UNIST) ranked among the top 200 universities in the world (109th), with the next Korean universities ranked 438th (KAIST) and 439th (Pohang University of Science and Technology [POSTECH]). In comparison, Sweden had 9, France had 23, and Germany had 14 universities among the top 400 institutions, indicating a more even distribution and consistency among the latter countries' universities in research quality. More specifically, the indicator for Nobel Prizes stands out as Korean universities have zero. In comparison, France has 65 in total, of which 36 are in "hard" sciences, including physics, chemistry and medicine.[10]

Korean universities are internationally competitive, as shown by their frequent appearance in the world's top 200 universities of the Times Higher Education and QS World University rankings, with six and seven institutions listed, respectively (Figure 4.10, Panel A). Relative to population levels, the number of top universities is therefore comparable to the United States and about twice as high as for France for these two rankings (Figure 4.10, Panel B). However, the gap between the top institutions and the bulk of HEIs seems bigger than in Japan, Germany and Sweden, confirming the impression of an HEI landscape dominated by a handful of universities – in terms of reputation and research output. Examining the socio-economic and redistributive effects of tertiary education according to Lee and Vignoles (2021), there are indications of considerable variations in prestige, reputation and quality between a small number of top HEIs and the remainder of less well-known HEIs, many of which were established after 2000 (Lee and Vignoles, 2021[36]).

Furthermore, the more research-quality-focused Shanghai Jiaotong University and CWTS Leiden Rankings offer a different picture. Both place only one Korean institution in the world's top 200, implying 0.19 per 10 million inhabitants, far less than many comparator countries except China (Figure 4.10, Panel B). This shows that although top Korean universities have a good reputation, attracting talented students and personnel as well as funding, the quality of the research, as measured by the share of top-cited publications, may lag behind that of HEIs in other countries at the innovation frontier.

These results should, however, be interpreted with caution due to the potential bias in university rankings in favour of western universities in terms of reputation and research quality. This may be due to historical and cultural factors. For instance, institutions in the United Kingdom benefit from long-established reputations worldwide, placing young universities in Asia at a disadvantage. Furthermore, affiliation, language and gender may constitute biases in peer reviewing since most relevant journals are western and rate articles according to their standards (Lee et al., 2013[37]). For instance, publications in English have a major advantage, benefiting institutions in the anglosphere (Jons and Hoyler, 2013[38]).

Figure 4.10. Number of top-200 universities in Korea and selected countries, 2021



Source: Times Higher Education World University Ranking, QS World University Ranking, Shanghai Jiaotong University Ranking, 2021; OECD calculations based on OECD (2022[39]), *Labour Force Statistics: Population and vital statistics*, oe.cd/il/54K, July 2022.

4.1.5. A few universities conduct most leading research in higher education institutions

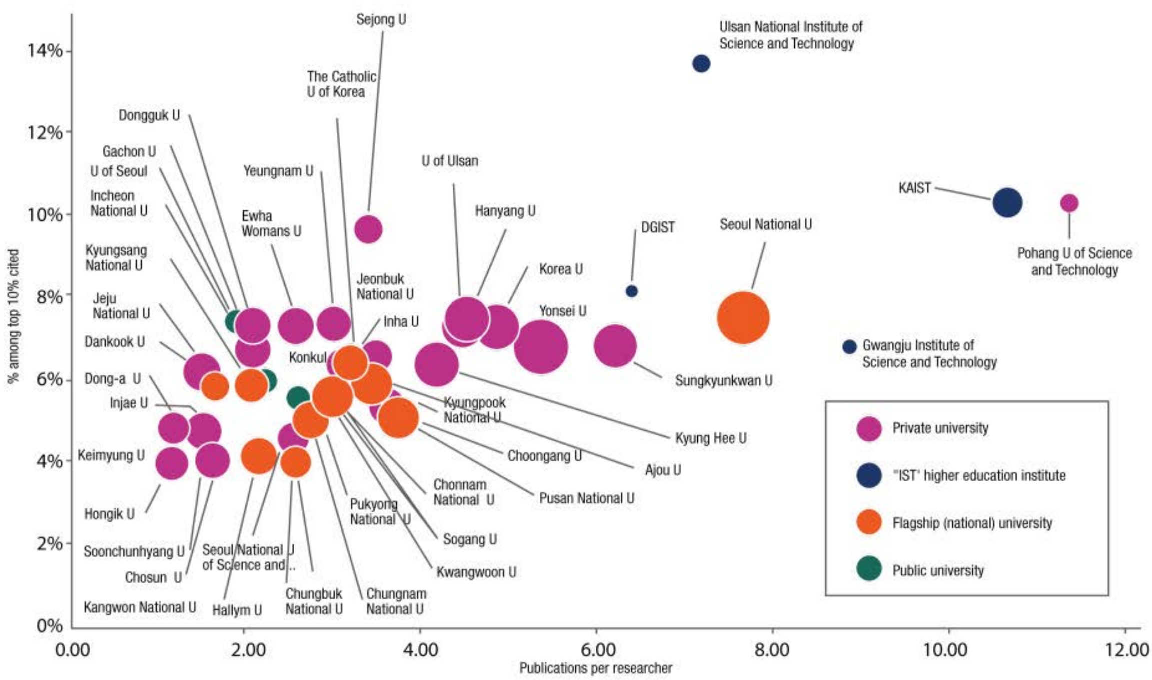
An analysis of the 45 universities listed in the CWTS Leiden Ranking makes it possible to compare the quantity and quality of research in Korean universities (Figure 4.11). A remarkable feature is that the quality and quantity of publications seem correlated to a certain extent, suggesting that universities with larger research groups and larger scientific output also produce higher quality output.

Productivity per faculty member varies widely, from about one per faculty member to more than ten for POSTECH and KAIST. This is largely linked to research funding, as discussed below, since larger funding per faculty member allows for the constitution of larger research groups and increases output per faculty member.

Concerning quality, three universities have scores above 10%, ranking them among the top 500 universities worldwide according to the Leiden ranking, including POSTECH, KAIST and UNIST. As a matter of comparison, top universities in the United States have a score above 20% (Rockefeller University, Massachusetts Institute of Technology [MIT], Princeton University, Caltech, Stanford, Harvard and University of California [UC] Berkeley), and a further 55 universities based in Europe, the United States, China, Singapore and Israel have between 15-20%.[11] The comparison within Korea shows the excellent performance of UNIST due to policies that will be discussed in more detail below. The other “IST” universities under MSIT (KAIST, Daegu Gyeongbuk Institute of Science and Technology [DGIST] and

Gwangju Institute of Science and Technology [GIST]) also perform quite well, both in quantity and quality. Regarding the flagship universities, SNU performs comparably to the IST universities. However, the other flagship universities are performing at lower levels. Some of the private universities perform quite well, in particular, POSTECH and Sejong University, and a number of others perform above average.

Figure 4.11. Quality and quantity of research in Korean higher education, 2022



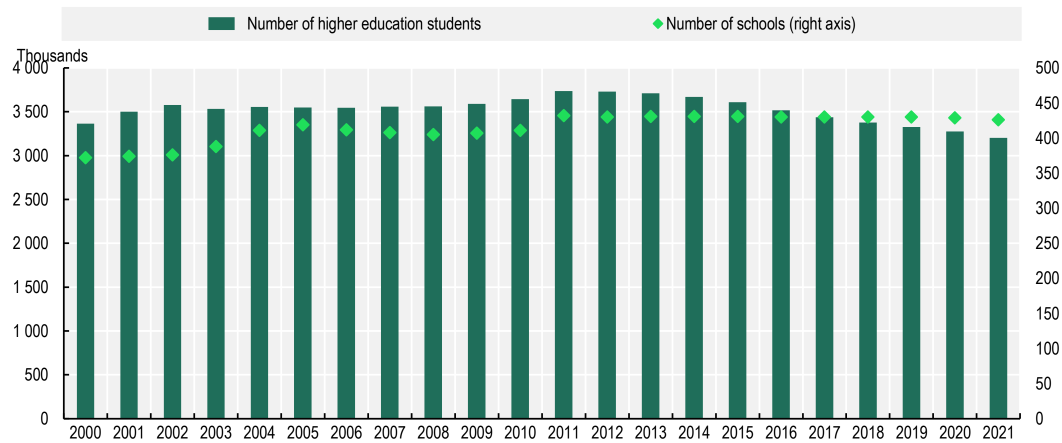
Note: On the horizontal axis, the average number of publications per faculty member is a measure of research productivity, while on the vertical axis, the percentage of publications among the top 10% cited journals is a measure of quality. The size of the symbol is proportional to the number of faculty.
Source: OECD analysis based on CWTS Leiden Data, https://www.leidenranking.com/information/data, 2022.

4.1.6. Technical skills are strong, but significant gaps persist across age groups

As of 2021, Korea had 3.2 million higher education students, about 500 000 less than in 2013, while the number of HEIs remained stagnant (Figure 4.12). The declining number of students and the ongoing tuition fee freeze have strained university finances, particularly in more regional parts of the country. This development is largely due to a steep decline in the overall population and the ongoing trend of students preferring to relocate to conglomerate areas for studies, where universities are more reputable and job prospects are better.

In 2019, Korea had the highest share of people aged 25-34 with tertiary education, close to 70% (Figure 4.13). It also had the largest difference in tertiary education between 25-34 year-olds and 55-64 year-olds, reflecting the rapid increase of tertiary educational attainment among the young and primary-age workforce in the past 30 years.

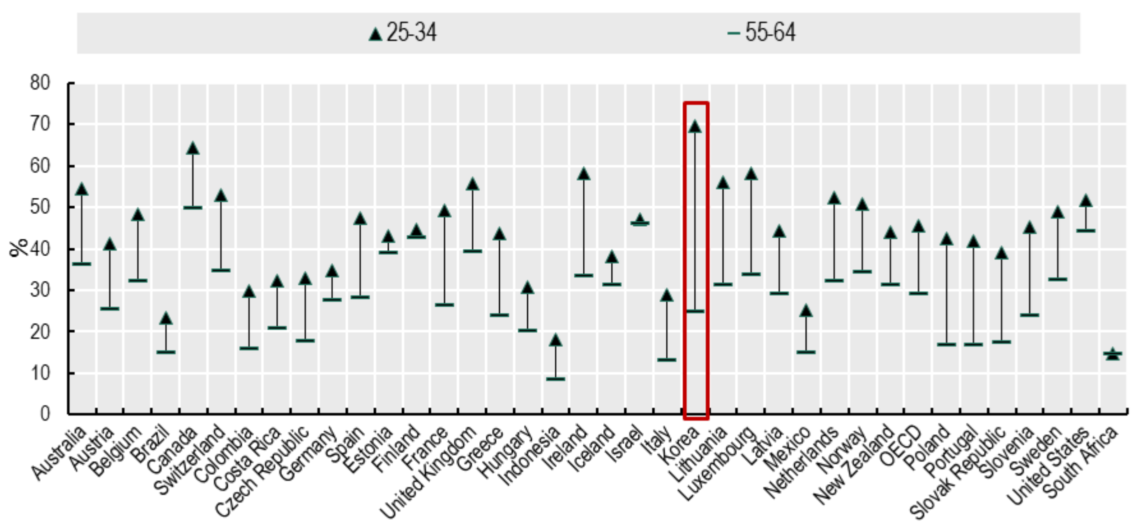
Figure 4.12. Number of higher education students and higher education institutions in Korea, 2000-21



Source: Ministry of Education Statistics, https://english.moe.go.kr/sub/infoRenewal.do?m=050101&page=050101&s=english, accessed June 2022.

Figure 4.13. Tertiary educational attainment in Korea and selected countries, 2020

Adults aged 25-34 and 55-64, Percentage



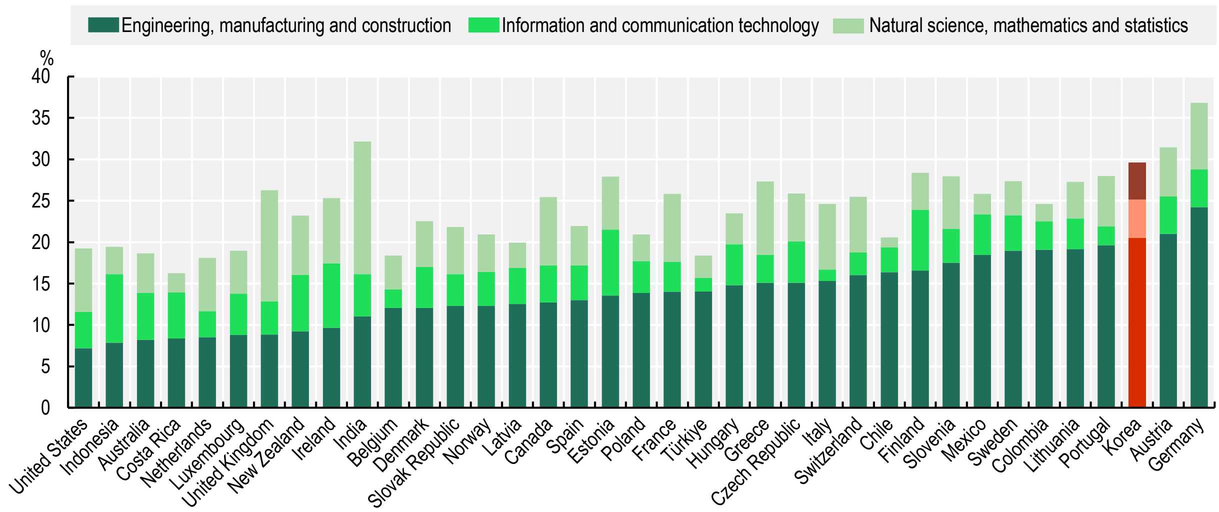
Source: OECD (2022[40]), *Education Statistics* (data), [oe.cd/dp/4Fn](oe.cd/dp/4Fn), August 2022.

National innovation systems are highly dependent on human capital, with science, technology, engineering and mathematics (STEM) skills being of particular relevance for innovation at the technological frontier. The Korean education system outperforms most OECD economies in terms of the quantity and quality of its students. Not only does Korea have the highest share of tertiary students among its 25-34 year-old population, with close to 70%, but it also has one of the highest shares of tertiary graduates in S&T fields, with almost 30% of all tertiary graduates (Figure 4.14, Panel A). Furthermore, Korean students are among the best-performing in OECD countries according to the 2018 results from the Programme for International Student Assessment (PISA), with almost 12% of students achieving top scores in science (Figure 4.14, Panel B).

Figure 4.14. Korean students and graduates in science and technology

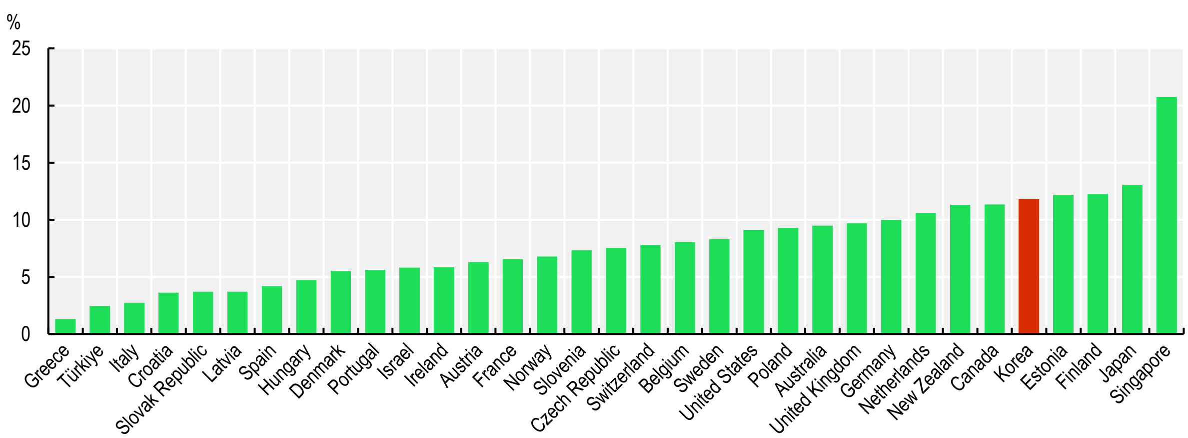
A. Share of tertiary graduates in selected sciences

Percentage of all tertiary graduates in all fields, 2019



B. Percentage of top students in all sciences

Percentage of top performers in science, based on PISA scores, 2018



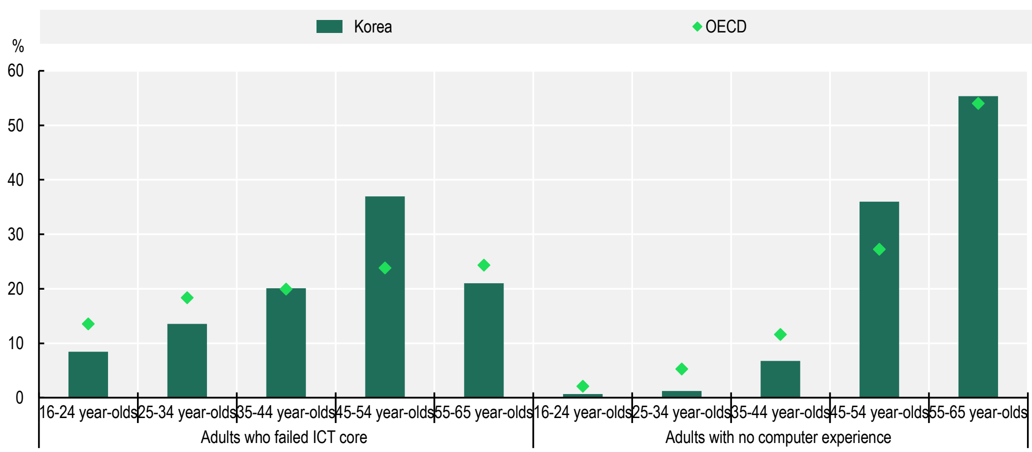
Note: With regard to Panel B, scientific performance, for PISA, measures the scientific literacy of a 15-year-old in the use of scientific knowledge to identify questions, acquire new knowledge, explain scientific phenomena, and draw evidence-based conclusions about science-related issues. It is not limited to the three fields under Panel A.

Source: OECD (2022[40]), *Education Statistics* (data), oe.cd/ds/4X0; OECD (2023[41]), "Science performance (PISA)" (indicator), https://doi.org/10.1787/91952204-en, June 2022.

However, skill levels vary significantly by age group, with middle- to old-aged workers lagging the well-educated and tech-savvy younger generation. For instance, the percentage of adults failing the information and communications technology (ICT) core test[12] in PIAAC, the OECD Survey of Adult Skills, is the second highest among OECD countries, with 9.1% in 2018. While 16-34 year-olds perform significantly better than the OECD average, almost 37% of those aged between 45 and 54 failed the ICT core test, and about the same percentage have no computer experience (Figure 4.15). Notably, 55-65 year-olds perform considerably better, which may result from training initiatives for senior citizens launched by the Korean government.

Skilled employees are among the most important resources for companies to innovate; however, there are indications that graduates' skill sets do not satisfy industry demands. First, weak ICT skills of many older workers may hinder basic operational efficiency, particularly for SMEs, which face a disproportionate challenge in attracting talented employees, as explained in Chapter 2. Second, skills shortages are commonly reported across OECD countries, although Korean SMEs are more likely to report them as a major challenge than large firms, whereas, in most OECD countries, the reverse is true (OECD, 2019[42]).

Figure 4.15. Adult ICT competencies and computer experience in Korea and OECD countries, 2018



Source: OECD (2018[43]), *Survey of Adult Skills (PIAAC)*, oe.cd/4Fk.

4.2. Classification of higher education and public research institutes

This section describes the classifications of PRIs and HEIs. The sections detail the performance, missions, funding, and governance structures of Korea’s HEIs and PRIs. After this initial presentation of the various types of PRIs, the remainder of the chapter will solely focus on GRIs.

4.2.1. Public research institutes

While there is no universal understanding with regard to the role and definition of PRIs, given the rapid pace of development in Korea, there have been many adjustments and rearrangements within its national PRI system. This section presents the categorisation of diverse organisations, notably government labs, technology centres, the scientific research institutes under MSIT, institutes of S&T and the so-called GRIs. The latter have provided the main support to industrial development over the past half-century; their roles are therefore undergoing the most significant change.

Government think tanks

Government think tanks are probably the oldest category of PRIs. These are traditionally owned, funded and steered by ministries or departments of the state. Their core task is to provide the ministries with research and information needed for policy development and regulation. For example, most coastal states have marine institutes that do scientific research on aquatic life but also perform regulatory tasks, such as monitoring marine pollution and estimating fish stocks as a basis for setting limits on allowable catches, and conforming with international treaties on fishing. Government think tanks often also produce public goods, such as weather forecasts, metrology, and geological mapping – generating information important to the government and wider society.

Generally, institutes that produce public goods also sell more specialised services, such as specific weather forecasts for large agribusiness firms, certification in relation to measurement, and detailed geological maps for mining companies. Where this is the case, their service revenues reduce the proportion of income they receive from the government. Often, they participate in government-funded research programmes. Since these opportunities to get external funding vary greatly by sector, the proportion of core funding to total income also varies greatly among government labs.

Government think tanks have played a role in Korea since the 1980s (or before). By and large, the think tanks that provide policy support and advice to ministries (Table 4.2) were formerly under the control of their respective ministries but were brought together by the Ministry of the Economy and Finance in 1999 and placed under the umbrella of the National Council for Economics, Humanities and Social Sciences (NRC).

Table 4.2. Policy support and advice bodies under Korea's National Council for Economics, Humanities and Social Science

Abbreviation	Name	Date established
AURI	Architecture and Urban Research Institute	2007/20
KDI	Korea Development Institute	1971
KDI School	KDI School of Public Policy and Management	1997
KEDI	Korean Educational Development Institute	1972
KEEI	Korea Energy Economics Institute	1986
KEI	Korea Environment Institute	1992
KICCE	Korea Institute of Child Care and Education	2005
KICE	Korea Institute for Curriculum and Evaluation	1998
KICJ	Korea Institute of Criminology	1989
KIEP	Korea Institute for International Economic Policy	1989
KIET	Korea Institute for Industrial Economics and Trade	1976
KIHASA	Korea Institute for Health and Social Affairs	1972
KINU	Korea Institute for National Unification	1991
KIPA	Korea Institute for Public Administration	1991
KIPF	Korea Institute of Public Finance	1992
KISDI	Korea Information Society Development Institute	1985
KLI	Korea Labour Institute	1988
KLRI	Korea Legislation Research Institute	1990
KMI	Korea Maritime Institute	1997
KOTI	Korea Transport Institute	1987
KREI	Korea Rural Development Institute	1978
KRIHS	Korea Research Institute for Human Settlements	1978
KRIVET	Korea Research Institute for Vocational Education and Training	1997
KWDI	Korean Women's Development Institute	1983
NYPI	Korea National Youth Policy Institute	1989
STEPI	Science and Technology Policy Institute	1987

Source: NRC (2021[44]), *Affiliate research institutes*, https://www.nrc.re.kr/menu.es?mid=a20202000000.

Technology centres

Korea has several technology centres, also called "special production technology research institutions", which provide technology support (often process-related), training and some collaborative R&D to established companies and SMEs. The Ministry of Trade, Industry and Energy (MOTIE) maintains the following centres:

- Korea Electronics Technology Institute (KETI)
- Korea Automotive Technology Institute (KATECH)
- Korea Photonics Technology Institute (KOPTI)
- Korea Research Institute for Fashion Industry (KRIFI)
- Korea Institute for Convergence Textile (KICTEX)
- Korea Textile Development Institute (KTDI)
- Korea Marine Equipment Research Institute (KOMERI)
- Korea Occupational Safety Research Institute (KOSRI)
- Korea Textile Machinery Convergence Research Institute (KOTMI)
- Research Institute of Medium and Small Shipbuilding (RIMS)
- Korean Institute of Footwear and Leather Technology (KIFLT)
- Korea Institute of Robotics and Technology Convergence (KIRO)
- Dyeing and Finishing Technology Institute (DYETEC)
- Korea International Trade Research Institute (KITRI).

One of the National Research Council of Science and Technology (NST) GRIs – the Korea Institute of Industrial Technology (KITECH) – has a similar function but appears to work at higher technological levels. KITECH supports technological development in areas such as clean tech and manufacturing technology for SMEs and, therefore, has seven regional labs in addition to its headquarters. Its budget is KRW 307 billion (about USD 291 million), of which 45.4% is government direct, 39.1% is government indirect, 12.6% is private, and 2.8% is other. It employs 1 142 people, of whom 86.1% work in R&D and the remaining 13.1% in management and administration (KITECH, n.d.[45]).

Other ministries still maintain (generally branch-specific) technology centres, providing some technical and business support and training. For example, the Korea Maritime Institute,[13] one of the NRC institutes, supports the Ministry of Oceans and Fisheries. At the same time, the sector is served by the Korea Institute of Marine Science and Technology Promotion (KIMST), whose goal is to “contribute to the marine industry by cultivating marine science and technology” (KIMST, 2021[46]).

Scientific research institutes under MSIT

Scientific research institutes, such as the Max Planck institutes in Germany and the Centre national de la recherche scientifique (CNRS) in France, largely do the same kind of research as universities and receive a high proportion of their income in the form of institutional funding. In some cases, they are organised as institutes because they rely on large scientific infrastructures, which would be beyond the means of a university to fund or manage. The Max Planck Society maintains its scientific research institutes outside the university system so that it can create, develop, and even shut down its institutes at will if their research trajectory and leadership run out of steam. In the former Soviet system, science was kept in Academy of Science institutes to keep dangerous free-thinking researchers away from impressionable students, who, therefore, received their higher education in universities dedicated to teaching. Quite a few post-Soviet states have transferred the Academy of Science institutes into the universities, enabling these universities to become Humboldtian, research-based institutions, simultaneously causing the university system to grow at the expense of the institute system. Some countries choose not to have scientific research institutes and assign responsibility for all state-funded basic and applied research outside government to universities.

Under current arrangements, MSIT oversees the scientific and technological institutes, which comprise a mix of different kinds of organisations. It manages the GRIs via the NST (discussed below) and directly controls a range of other institutes (Table 4.3).

Table 4.3. Government research institutes and public research institutes that report to Korea's Ministry of Science and ICT

MSIT GRIs under the National Research Council of Science and Technology (NST)		PRIs reporting directly to MSIT	
KIST**	Korea Institute of Science and Technology	R&D-focused (scientific research institutes)	
(GTC)*	Green Technology Centre Korea	(KIAS)	Korea Institute for Advanced Study
KBSI*	Korea Basic Science Institute	IBS	Institute for Basic Science
KASI*	Korea Astronomy and Space Science Institute	(NIMS)	National Institute for Mathematical Sciences
KRIBB*	Korea Research Institute of Bioscience and Biotechnology	(KBRI)	Korea Brain Research Institute
KISTI**	Korea Institute of Science and Technology Information	KIRAMS	Korea Institute of Radiological and Medical Sciences
KIOM*	Korea Institute of Oriental Medicine	Universities	
KITECH**	Korea Institute of Industrial Technology	KAIST	Korea Advanced Institute of Science and Technology
ETRI**	Electronics and Telecommunication Research Institute	GIST	Gwangju Institute of Science and Technology
(NSR)*	National Security Research Institute	DGIST	Daegu Gyeongbuk Institute of Science and Technology
KICT**	Korea Institute of Civil Engineering and Building Technology	UNIST	Ulsan National Institute of Science and Technology
KRRI*	Korea Railroad Research Institute	UST	University of Science and Technology
KRISS**	Korea Research Institute of Standards and Science	Miscellaneous	
KFRI**	Korea Food Research Institute	(NNFC)	National NanoFab Center
(WIKIM**)	World Institute of Kimchi (under KFRI)	KANC	Korea Advanced Nano Fab Center
KIGAM**	Korea Institute of Geoscience and Mineral Resources	KISTEP	Korea Institute of S&T Evaluation and Planning
KARI**	Korea Aerospace Research Institute	COMPA	Commercialisation Promotion Agency for R&D Outcomes
KIER**	Korea Institute of Energy Research	(KIRD)	Korea Institute of Human Resources Development in Science and Technology
KERI**	Korea Electrotechnology Research Institute		
KRICT**	Korea Research Institute of Chemical Technology		
KIT*	Korea Institute of Toxicology		
KIMM	Korea Institute of Machinery and Materials		
KAERI*	Korea Atomic Energy Research Institute		
KIMS*	Korea Institute of Materials Science		
KFE**	Korea Institute of Fusion Energy		

* Formerly under the Korea Research Council of Fundamental Science.

** Formerly under the Korea Research Council for Industrial Science and Technology.

Source: National Research Council of Science & Technology (2022[47]), *Home page*, https://www.nst.re.kr/eng/index.do; individual institute websites.

MSIT currently has five scientific research institutes directly reporting to it. They make up a very small fraction of the PRIs in Korea and are, at this stage, also small compared to equivalent institutes internationally. This is consistent with the policy of focusing growth on more fundamental research in the university sector.

Three scientific institutes – namely KIAS, the IBS and the KBRI – network across the national and international research communities, aiming to strengthen basic research in Korea. They are consistent with an effort to increase the volume of basic research in Korea largely by expanding university research and networking across the universities and existing PRIs. The other two are specialist applied research centres (NIMS and KIRAMS).

The largest of the scientific research institutes is the IBS, which was established in 2011. IBS has 895 employees, of whom 56% are researchers, and the rest are administrators and technical staff. It is closely affiliated with the University of Science and Technology (UST), as manifested by the joint establishment of the IBS Campus, UST, which offers research-centred education by allowing students to participate in research. UST was also established in 2011 and provides a framework for co-operative research and higher education among leading Korean universities and research institutes. IBS specialises in comparatively long-term projects involving large groups of researchers and, in some cases, specialised scientific infrastructures, an aspect that may differentiate its research from that of the universities. It has so far built up 31 research centres, each normally set up for five years around a leading scientist, then extended for three years at a time subject to satisfactory evaluations. Its governance structure is designed partly to ensure that IBS is integrated into the global research system, and IBS emphasises the employment of researchers from abroad.

There are several other scientific research institutes that are important to mention. For example, KIAS was set up in 1996 on the model of the Institute of Advanced Study at Princeton University in the United States, working in maths, physics and computational science. It has about 150 researchers and aims to welcome visiting researchers from abroad to network with Koreans working in international research in the field. KBRI is also small and aims to act as a national hub for Korean brain research and encourage links with the international research community. NIMS (2005) works on mathematics for industry and medicine. Finally, KIRAMS dates from 1962/63, is attached to a hospital and does specialist research in medical radiology.

Institutes of science and technology

As Table 4.3 shows, there are five institutes of S&T – actually, universities, in the same sense that MIT is an "institute" of technology –that report to MSIT. They have legislative and governance bases different from national universities in the sphere of the Ministry of Education and more generous institutional funding for research.

Other MSIT institutes

Again, as Table 4.3 shows, MSIT additionally has two institutes dedicated to providing research infrastructure: an agency promoting the commercialisation of research results and a further institute working to develop human resources in S&T. The other institute shown – KISTEP – provides S&T policy formulation, co-ordination, evaluation and management of national R&D projects, as stipulated by the Framework Act on Science and Technology. The NRF and the Institute for Information and Communications Technology (IITP) act as funding agencies to MSIT.

Government research institutes

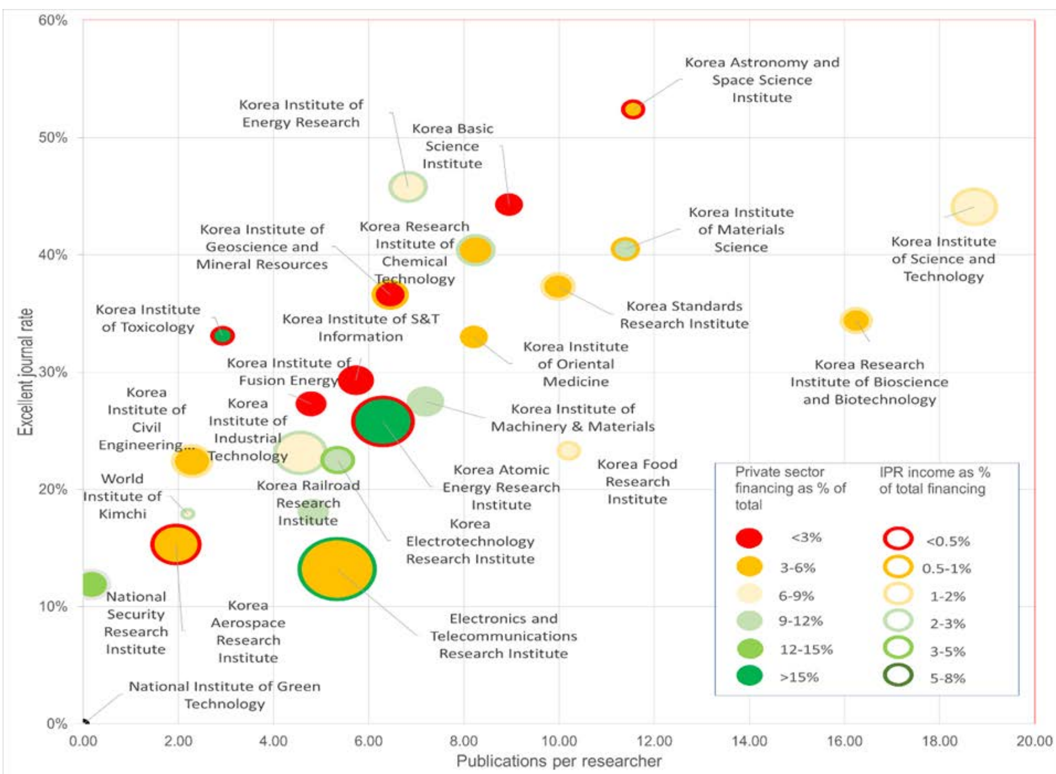
The GRI group shown in Table 4.3, which MSIT controls indirectly via the NST, comprises institutes formerly under the Korea Research Council of Fundamental Science and Technology and the Korea Research Council for Industrial Science and Technology. The set of GRIs is somewhat heterogeneous, mixing institutes that support sectors where the state is in control or a major player (atomic energy, fusion, railroads) with those dealing with more open industry structures where beneficiaries are more likely to be in the private sector. Those originating with the Korea Research Council for Industrial Science and Technology are most closely analogous to research technology organisations (RTOs).[14]

The GRI landscape is diverse and evolving

While there is an ongoing debate about the role of the GRIs, it is important to recognise that the GRIs have been and are evolving. The pattern of publications (in Scopus) Choung & Hwang suggests that while the comparatively small volume of basic research in Korea before 1990 was not very thematically focused, the growing effort from the 1980s by the PRIs and industry in response to thematically focused research programmes aimed at building industrial capacity and strength led to a focusing of the effort on the engineering-related needs of growing chaebol. By the early 2000s – when the relative share of government R&D investment started to shift from the PRIs towards the universities – the major companies had established their own basic and applied research capacity. Government-funded research across the GRIs and universities became more diversified, e.g. moving more strongly into the biological sciences. This can be seen as marking a transition from the thematically focused research pattern needed for catch-up towards the more comprehensive pattern of basic and applied research associated with a more mature economy (Choung and Hwang, 2013[48]).

The complexity of the GRI landscape can be appreciated in Figure 4.16, as presented according to scientific output, intellectual property revenue (IPR), and private-sector-financing share. Similar to the finding for universities, the quality and quantity of publications seem correlated to a certain extent, suggesting that institutes with larger scientific output also produce higher quality output.

Figure 4.16. Shares of research, intellectual property revenue and private sector financing of Korean government research institutes, 2022



Note: On the horizontal axis, the average number of publications per researcher is a measure of research productivity, while on the vertical axis, the percentage of publications among the "Excellent journal rate" measures the proportion of papers published in the top quartile according to the SCImago Journal Ranking, and is a measure of quality. The size of the symbol is proportionate to the number of staff, while the colour indicates the magnitude of IPR income as a percentage of total financing and the percentage of private financing.
Source: OECD analysis based on KIST data, 2022.

Several institutes show high productivity and high quality in scientific output, including the Korea Institute of Science and Technology (KIST), the oldest GRI, the Astronomy and Space Science Institute, the Bioscience and Biotechnology Institute, the Institute for Energy Research, the Korea Basic Science Institute, the Institute of Materials Science, the Korea Standards Research Institute, the Korea Research Institute of Chemical Technology, the Korea Institute of Geoscience and Mineral Resources, and the Korea

Institute of Oriental Medicine. Those institutes have a private sector co-financing share with less than 15% of the total and a relatively modest fraction of IPR (the highest being in the Institute of Energy with 4%, followed by the Institute of Chemical Technology at 3.4% and the Institute of Materials Science at 2.6%).

Another group of institutes has a high fraction of private sector financing (green symbols showing those with more than 9%including the National Security Research Institute, the Electrotechnology Institute and the Railroad Research Institute. It could be argued that they act as research and technology organisations. Some of these also have sizeable income from IP transfers.

The Electronics and Telecommunications Research Institute (ETRI) is a special case. Due to its extremely successful performance in raising project-based funding from the government, it does not use a large fraction of private sector funding. Rather, the project team has heard that ETRI often competes with the private sector. Nevertheless, ETRI is the absolute champion of IP transfer, as income from IP amounts to 7.8% of total financing.

The positioning of the Korea Aerospace Research Institute and the National Security Research Institute may not be directly comparable due to the confidential nature of their deliverables, which reduces the part of published results.

Several other GRIs are positioned “in-between”, with modest scientific results and low engagement with the private sector. Further auditing could be useful to identify other potential reasons and bottlenecks contributing to these outcomes.

4.2.2. Higher education institutions

There were 426 HEIs in Korea in 2021, with 190 being recognised universities offering at least four-year undergraduate degrees and/or graduate education; 134 junior universities (with two-to-three-year degrees as opposed to the standard four years); 45 graduate schools; 10 universities of education (where teachers of elementary schools are educated); and 45 technical colleges and others, including cyber and corporate colleges, which are intra-firm universities established by companies to develop employee skills according to their needs (Ministry of Education, 2022[49]). This analysis focuses on the officially licensed and accredited universities, the vast majority of which are private (156) (Ministry of Education; Korean Educational Development Institute, 2019[50]).

National flagship universities

Article 3 of the Higher Education Act distinguishes two types of public universities: public universities, established and managed by the central government, and regional universities, established and managed by municipalities. Today, there are 23 public universities and only 1 regional university (the University of Seoul, which was established by the city of Seoul).

Article 10 of the Higher Education Act allows universities to establish a council to support the development of higher education. The “regional hub national university” – or “flagship university” – comprises nine public universities in different regions of Korea. These are typically the oldest and largest institutions of a region with good financing and comparatively low tuition fees. They are also often preferred by students compared to local private universities. Their historical mission has been to increase the educational quality in all Korean regions to reduce the educational gap between Seoul and the provinces and between private and public institutions. Nevertheless, today’s role of national universities is more difficult to define, as stakeholders on university boards, including government and business representatives, vary in their perspectives on the institutions’ goals, and their visions no longer necessarily include the specific needs of the provinces they are in (Kim and Yeom, 2017[51]).

In response to decreasing student enrolment, many public universities have now integrated into national flagship universities (Paik, 2020[52]). For example, in 2008, Sangjoo University in the North Gyeongsang province merged with Kyungpook University, now a flagship university.

Private universities

The introduction of private universities has significantly driven the expansion of higher education access in Korea (Chae and Hong, 2009[53]). Between the 1970s and the early 2000s, Korea saw the largest expansion of participation in higher education in the history of higher education (World Bank, 2002[54]), largely due to the massive rise in private institutions in the same period. While private universities are established and managed by a corporation or private person separated by the state, their establishment is approved by the Minister of Education in accordance with the establishment standards set forth in Article 10 of the Higher Education Act. Most universities in Korea are private universities that largely rely on students' tuition fees since government subsidies are relatively low. They are less regulated, e.g. in terms of enrolment caps, tuition fees or limitations in the availability of double majors, than public universities or universities established by not-for-profit educational corporations. The government retains higher control of management and operations, which are overseen by the Ministry of Education, as originally stipulated in the Private School Act of 1963 (Chae and Hong, 2009[53]). Private universities need, however, to also be certified and accredited by the Ministry of Education based on its curriculum, facilities and faculty composition requirements, among others. The accreditation process is undertaken by designated institutes, such as the Korea University Accreditation Institute (Korean Council for University Education, 2022[55]). Private universities are also concerned with the rapid decline in the number of students accompanied by severe financing challenges, risking mass closures of private HEIs. According to the Korean Educational Development Institute, the net loss of private universities was KRW 268 billion in 2018, a dramatic increase from KRW 14 billion in 2016 (Ko, 2021[56]).

Clustering

Classifying and hierarchising HEIs is a challenging task since it varies widely according to the variables used. In this attempt, an approach has been adopted to classify HEIs based on their research performance. Therefore, this should not be seen as a ranking of overall performance, as teaching aspects are not taken into account here. Clustering models have been applied to categorise Korean universities into different clusters. [15]

Four variables were introduced to conduct the analysis: 1) percentage of publications among the top 10% cited journals; 2) publications per faculty member; 3) research expenditure per faculty member; and 4) ratio of graduates to total students. For each variable, a score was computed according to the formula:

$$\text{Score\_i} = (\text{value\_i} - \text{average}) / \text{standard deviation}$$ [16]

This makes it possible to combine the different variables in the computation.

Data provided by the NRF (2021[57]) and the Carnegie Classification of Institutions of Higher Education (2021[58]) were used. A total of 45 Korean and 104 US universities were taken into account. Table 4.4 presents the results of the cluster analysis.

Table 4.4. Korean university cluster analysis

Cluster	Korea					United States				
	Percentage of publications in top 10% cited journals	Publica tion/ faculty	Expenditure/ faculty (USD thousands)	Top-cited publica-tions per faculty	Graduate ratio (%)	Percentage of publications in top 10% cited journals	Publica-tion/ faculty	Expendi-ture/faculty (USD thousands)	Top-cited publica-tions per faculty	Gradu-ate ratio (%)
1	9.5	8.7	323	0.8	62.6	21.9	17.1	2 259	3.7	80.4
2	7.1	5.2	170	0.4	21.8	16.3	5.4	466	0.9	52.7
3	6.3	2.9	79	0.2	8.8	10.0	2.8	207	0.3	32.9
4	4.4	1.6	44	0.1	5.9	11.2	2.3	190	0.3	63.6

Note: "Top-cited" refers to the PP (top10%) of the CWTS Leiden Ranking, that is, the proportion of a university's publications that, compared with other publications in the same field and the same year, belong to the top 10% most frequently cited (CWTS Leiden Ranking, 2022[59]). "Publication/faculty" and "Expenditure/faculty" refer to the average number of articles published per faculty and the average research expenditure received per faculty, respectively. The "Top-cited" and "Publication/faculty" are multiplied to calculate "Top-cited publication per faculty", which is the average number of the top-cited articles published per faculty. For example, a faculty member from a Korean university in Cluster 1 published 0.8 articles classified as top-cited. Finally, "Graduate ratio" shows the share of graduate students as a percentage of registered students.
Source: OECD calculations based on NRF (2021[57]), *Analysis Report on University Research Performance*, https://www.nrf.re.kr/cms/board/library/view?menu_no=419&o_menu_no=&page=1&nts_no=168743&nts_cat=REPORT_L_02&search_type=NTS_TITLE&search_keyword=&nts_cat=REPORT_L_02 and The Carnegie Classification of Institutions of Higher Education (2021[58]), *Carnegie Classifications*, https://carnegieclassifications.acenet.edu/.

On average, universities in the first cluster are 1.3 standard deviations above the mean in terms of publication per faculty; they can thus be classified as "research-active" universities. Not surprisingly, the most prestigious universities – both in terms of reputation and research performance – are present. For Korea, IST universities, known for the generous amount of subsidies and grants that are given to them each year, are ranked in the first cluster, followed by the most prestigious private and flagship universities in the second cluster. The only non-IST universities classified as research-active are POSTECH and SNU. This sharply contrasts with the case of the United States, where the four research-active universities – Harvard University, California Institute of Technology, Medical University of South Carolina and Rockefeller University – are all private universities. With the exception of Harvard University, these universities are STEM-oriented, with the majority or the totality of students attending graduate-level programmes.

In Korea, the second cluster includes Sungkyunkwan University, Yonsei University, Korea University and Hanyang University. These four private universities are well known for their competitive application process and are located in Seoul. Similarly, the most prestigious universities in the United States – including the "Ivy League schools", such as Yale University or Princeton University – belong to the second cluster. For both countries, the third cluster is the largest of the four clusters. For Korea, this is also where most of the flagship universities are located. Lastly, Korea's fourth and last cluster is mostly composed of private universities in provinces. It is important to note that the last cluster in the United States includes some of the country's top-ranked universities, such as Georgetown University.

Overall, research-active universities in Korea are showing lower performance in research than US institutes. For instance, US universities in Cluster 1 are twice as productive (as measured by publication per faculty member) and 2.5 times more likely to publish an article among the top 10% cited than Korean universities of the same cluster. In Clusters 2, 3 and 4, researcher productivity is comparable between Korea and the United States, while a significant gap persists in the percentage of top-cited papers. Overall, the analysis of clusters indicates that Korean universities, even those classified as the most research-oriented, show lagging results in terms of research quality and quantity.

There are even more striking differences in research funding per faculty member. For example, US universities in Cluster 1 received around USD 2.26 million per faculty for research expenditure, whereas Korean universities received USD 0.32 million (or USD 0.43 million measured at purchasing power parity

[PPP]), which is around seven times less (or five times less at PPP). In subsequent clusters, the gap is less significant, but funding per researcher remains 3-4 times higher in the United States (2-3 times at PPP). Another apparent difference is in the ratio of graduate students. For every cluster, the average ratio of graduate students is higher in the US institutes.

Nevertheless, it is important to highlight that Korean universities seem to utilise their research funding more efficiently. For Korean research-active universities, every USD 50 000 generate a publication, whereas the number surges to USD 132 000 for the United States. When only top-cited articles are taken into account, the Korean research-active universities produce one of these high-quality publications for every USD 540 000, while top US universities need USD 610 000. The efficiency of Korean research activities is expanded further in the funding section below.

4.3. Missions of government research institutes and higher education institutions

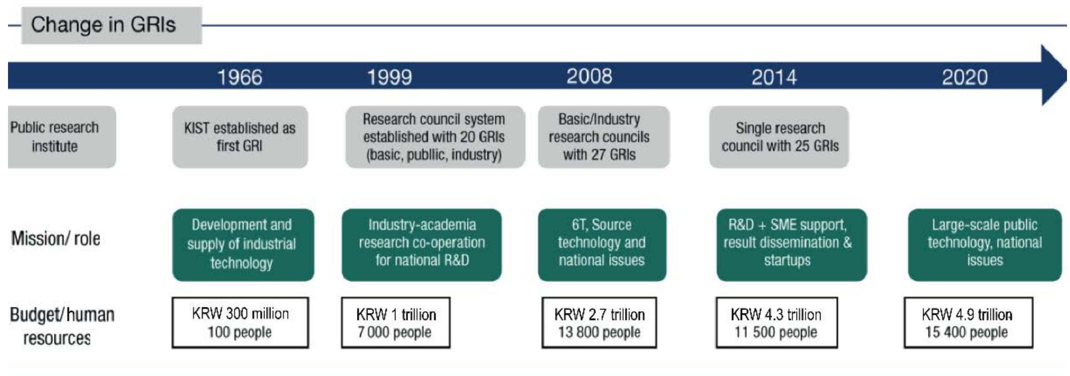
4.3.1. Government research institutes

The mission of the GRIs has changed considerably since the first institute, KIST, was founded in 1966 (Figure 4.17). Originally created to produce and provide the technology needed for Korea's industrial development and catch-up, they accounted for the bulk of the country's total R&D expenditure in the early phases of the establishment of a Korean innovation system, or 84% in 1970 (OECD, 2009[60]). In this period, the GRIs differentiated themselves according to the technology needs of respectively prioritised industries, such as shipbuilding, geoscience, electronics, telecommunications, energy, machinery and chemicals. In their heyday in the 1970s, in addition to supplying strategic industries with relevant technology, the GRIs served an important capacity-building function for industry, training a critical mass of researchers who eventually moved to corporate research centres (OECD, 2009[60]). A more detailed discussion of the GRIs' mission is found in the governance section below.

In 1999, the Act on the Establishment, Operation and Fostering of Government-funded Science and Technology Research Institutes, etc. created three research councils – basic, industrial and public – to oversee the GRIs, with each research council answering to a different ministry (Lee et al., 2012). As major industry's need for the GRIs declined, on the one hand, and as the government expanded the education and research functions of the higher education system, dependence on the GRIs declined further. After Lee Myung-Bak became president in 2008, he restructured the public council into the other two and placed the basic research council under the Ministry of Education and Science and Technology (MEST) and the industrial council under the Ministry of Knowledge Economy (MKE) (Lee, 2011[61]). In 2014, the basic and industrial research councils were consolidated into the single National Research Council of Science and Technology (NST) under the Ministry of Science, ICT and Future Planning, which became the MSIT in 2018.

Figure 4.17 shows how the mission of the GRIs has evolved in line with the pattern of development. KIST and its spin-offs aimed to secure the technologies needed to develop industry. By the turn of the millennium, industrial capabilities were sufficient for the GRIs to collaborate with industry on R&D rather than importing, adapting and developing technology. The focus moved towards specific national technology needs in the 1990s, and the GRIs' target group was extended from large companies to include SMEs.

Figure 4.17. Evolution of the mission of Korea's government research institutes



Source: STEPI (2021[62]), *Background Paper - OECD Reviews of Innovation Policy: Korea 2021*.

While recognising that the GRIs have evolved and become more diversified since the 1980s, there is still room for improvement in defining the current role of government-funded research institutes in the national innovation system. They appear to be expected to close knowledge gaps in socially and industrially important areas that private industry is unwilling or unable to pursue. With the growing importance of universities and industry to the national innovation system and Korea's transition process from catch-up to an innovation leader, the role of GRIs has further room for improvement. The government has subjected GRIs to a "roles and responsibilities" (R&R) exercise through which they define their own R&Rs. It does not intend clear distinction across GRIs, but some have a stronger basic science focus (e.g. KASI), and others behave more similar to RTOs (e.g. KITECH).

Nevertheless, there is no clear distinction, and it remains to determine if GRIs' R&Rs are sufficiently aligned with the national strategy and innovation system. The official role of GRIs is to carry out public-purpose R&D based on national missions in accordance with domestic laws and their articles of association.

Table 4.5. Major research projects based on Korea's government research institutes' roles and responsibilities

Major research projects	Major GRIs responsible
Public safety and life	KRIBB, KIST, KIMS, KOTI
DNA (Data network AI)	KIST, ETRI, KISTI, KARI
Science infrastructure and service	KIST, ETRI, GTC, KAERI, KFE, KRIBB
Sustainable society	KRICT, ETRI, KERI, KIER
Big science and society-based science	KASI, KICT, KAERI, ETRI, KIGAM
Regional development technology	KITECH, KICT, KIMM, ETRI
North-South science technology	KRIBB, KISTI, KICT, KRRI
Core future industry technology	KIST, ETRI, KIOM, KISTI

Source: Yu (2020[63]), *R&R-based research on project efficiency and linkage: Focusing on materials, parts, and equipment*, https://www.kistep.re.kr/reportDetail.es?mid=a10305040000&rpt_no=RES0220200208.

Under the administration of former President Moon, GRIs re-established their R&R per their research expertise and societal needs. Eight major research projects were defined (Table 4.5), and the funding was distributed accordingly (Yu, 2020[63]). Table 4.5 shows the major GRIs responsible for each research project. The five most funded GRIs are often the major research institutes of multiple research projects. Project team interviews suggest that perhaps half the GRIs have completed this exercise. ETRI has used it to pivot its field of activity from electronics, widely defined, to a strong focus on AI, with the intention of being the main pole enabling Korea to catch up and build capacity in AI technologies (against a background of massive investments by the United States, China, Germany and elsewhere). Table 4.6 sets out the current missions by government research institutes.

Table 4.6. Korea's government research institutes' current missions

Institute	Mission
Korea Institute of Science and Technology (KIST)	Solving national and social challenges and securing growth engines through leading and innovative research Focusing on various challenges, including population ageing, the Fourth Industrial Revolution and sustainable society by developing technologies for climate, disaster and safety
Green Technology Center	Promoting the advancement of the national climate industry and contributing to global efforts in responding to climate change
Korea Basic Science Institute (KBSI)	Conducting R&D on research facilities and equipment and analytical S&T, and joint research and support for promoting basic science
Korea Astronomy and Space Science Institute (KASI)	Developing and operating research facilities as well as public outreach for astronomy and space science/technologies related to space situational awareness Promoting collaborative R&D projects with public and private sectors
Korea Research Institute of Bioscience and Biotechnology (KRIBB)	Carrying out R&D activities and related projects in the field of bioscience and biotechnology in joint efforts with other research institutes, academia and industries to disseminate the results of scientific research and technological development in Korea and abroad Supporting the establishment of public infrastructure, government-funded think tanks, nurturing talented human resources, supporting commercialisation of SMEs
Korea Institute of Science and Technology Information (KISTI)	Taking the lead in resolving national and societal issues and innovating Korea's R&D through supercomputing and AI Securing global leadership in supercomputing and promoting an AI-driven infrastructure to address societal challenges
Korea Institute of Oriental Medicine (KIOM)	Professional and systematic R&D activities on Korean medicine theories, technologies and services and disseminating their outcomes, thereby contributing to the development of relevant industries and the improvement of public health
Korea Institute of Industrial Technology (KITECH)	Supporting the industry sector, especially SMEs, as an application-oriented research institute Focusing on three key research areas: advanced manufacturing technology, industrial technology convergence, and sustainable manufacturing system technology Strengthening field-oriented support for SMEs, running three research centres and seven regional divisions
Electronics and Telecommunications Research Institute (ETRI)	Contributing to the nation's economic and social development through R&D and distribution of industrial core technologies in the field of information, communications, electronics, broadcasting and convergence technologies Preparing for future growth by vitalising creative and challenging research
National Security Research Institute (NSRI)	Pan-national dimensional development of information security technology, including technology corresponding to national cyber security
Korea Institute of Civil Engineering and Building Technology (KICT)	Developing technology for national infrastructure facilities to address natural disasters and for eco-friendly land development R&D co-operation with governments, the private sector, multinational corporations and non-governmental organisations, as well as the implementation of government or private-sector-commissioned technology services Technology transfer related to land and construction, adaptation, commercialisation co-operation, and support for SMEs Nurturing high-skilled human resources in primary areas, the establishment of technological policies, standards and criteria for land and construction, implementation support for major national projects
Korea Railroad Research Institute (KRRI)	R&D on various railroad systems (high-speed, urban, nationwide and international), next-generation public transportation systems, railroad safety, standardisation, railroad policy and logistics technology Co-operation, support, and technology commercialisation with SMEs and other business groups in the industry Expanding public interactive research and strengthening co-operation among railway operation and construction organisations Establishing researcher-focused R&D innovative ecosystems with autonomy and responsibility
Korea Research Institute of Standards and Science (KRISS)	Establishing, maintaining and improving national measurement standards Conducting R&D in measurement S&T

Institute	Mission
	Disseminating measurement standards and technology and providing support services
Korea Food Research Institute (KFRI)	Researching longevity science, functional foods, safe distribution and food processing technology Disseminating research outcomes, providing technological support and doing research on the reinforcement of public functions for the development of industries such as food, agriculture, forestry and fisheries and for improvement in quality of life
World Institute of Kimchi (WIKIM)	Performing R&D related to kimchi to lead national technological innovation, nature and develop the kimchi industry to boost national growth
Korea Institute of Geoscience and Mineral Resources (KIGAM)	Geo-research on land and ocean, geo-exploration on deep subsurface resources and utilisation, development of new geo-technology on geo-hazards and global climate change
Korea Institute of Machinery and Materials (KIMM)	Researching humanity, the future of mechanical technology with partners from the public and private sector
Korea Aerospace Research Institute (KARI)	Contributing to the solid development of the national economy and enhancement of national life through exploration and technological advancements, development and dissemination in the field of aerospace S&T
Korea Institute of Energy Research (KIER)	Contributing to the creation of national growth engines and the development of the national economy through R&D and disseminating achievements in the energy technology area
Korea Electrotechnology Research Institute (KERI)	Conducting R&D on power technologies and power systems of renewable energy / electrical apparatus / electrical parts and materials/convergence technology based on electro-medical devices and electrical technology R&D co-operation with the government, private sector and organisations and consignment of technical services Providing support and technology commercialisation for SMEs Supporting human resources and establishing technical policies in key mission areas
Korea Research Institute of Chemical Technology (KRICT)	Reinforcing the competitiveness of chemical industries and contributing to the resolution of national and social problems by performing R&D in chemical and convergence technologies and providing public infrastructure and services
Korea Institute of Toxicology (KIT)	Contribution to public health and welfare enhancement and to the development of national industries by safety assessments of chemical and biological materials
Korea Atomic Energy Research Institute (KAERI)	Building a safe society centred on people and the environment through reliable, innovative nuclear technology Contributing to academic advancement, energy acquisition, and utilisation of nuclear energy through active R&D in related fields
Korea Institute of Materials Science (KIMS)	Comprehensive range of activities related to materials technology, including R&D, inspections, testing and evaluation, and technical support Striving for leadership in advanced material technology in Industry 4.0 and localisation of materials in response to Japanese export restrictions Mapping the scattered research capabilities in the domestic materials science field and playing a pivotal role in co-operation of industry, academia and research institutes
Korea Institute of Fusion Energy (KFE)	Promoting new research, technology support, development, demonstration and dissemination in the field of fusion energy Training nuclear fusion personnel in co-operation with industry and commercialisation of technology

Source: Individual institute websites, accessed in 2022.

In relation to the GRIs, since about 2000 – when the introduction (2003/04) of technology transfer offices (TTOs) in GRIs and universities induced a focus on patenting in GRI incentive systems, and the shift in policy towards funding research in universities put more attention on publication in the indexed scientific literature – studies of technology transfer and acquisition and the performance indicators used in evaluating projects and research-performing organisations in Korea overly relied on IP and publication indicators. These provide an incomplete picture of technology transfer and capacity building. Furthermore, the ability of patent- and publication-based performance indicators to induce perverse behaviour is well known. The temptation for analysts to use these indicators is understandable, as they appear to offer homogenous and quantifiable ways to understand performance, even though both have different meanings in different fields. The propensity to publish or patent varies among disciplines and technologies and can change over time. There are many other modes of knowledge exchange through which technological knowledge can be developed and exchanged, including education and training, personnel mobility, joint research, reverse engineering, provision of consulting or advisory services, testing and certification, among others.

Historically, based on surveying 500 manufacturing firms benefiting from technology transfer from GRIs and universities in 2004-06, Eum and Lee (2009[32]) sharply criticised the previously strong focus of GRI performance indicators on formal patents. They analysed five types of knowledge transfer: informal activities; education; R&D co-operation and technical support; patents and licensing; and business activity. Of these, business activities have little effect on company innovation. All four other modes of knowledge transfer from universities facilitate product innovation, while only IP-based transfer from PRIs strongly influences product innovation. However, Eum and Lee point out that informal activities, education, R&D co-operation and technical support from GRIs all facilitate process innovation.

ETRI provides a well-documented and useful description of contributions from university-industry collaboration to industrial innovation (Paik, Park and Kim, 2009[64]). It was central in bringing electronics technologies prioritised by the government to Korea and transferring them to the companies that went on to establish themselves among the world leaders in electronics markets. At this stage, ETRI was also heavily engaged in training various levels of the industrial workforce in the new technologies. As company capabilities rose, ETRI's role refocused towards smaller, supporting projects and new, smaller companies. ETRI was also an important source of experienced researchers for universities, industry and government (Table 4.7) (Paik, Park and Kim, 2009[64]).

Table 4.7. The changing management system at ETRI and the institute's industrial contributions

	First generation (1985-91)	Second generation (1992-97)	Third generation (1998-2000)
Mission and objectives	Technology development of large-scale national R&D through internal development and absorptions of internationally transferred technology	Development of an efficient and effective R&D management system	Value creation through cost minimisation and royalty maximisation
Scale and selection of R&D projects	Limited number of large-scale R&D projects suggested by government	Multiple and small-scale projects related to previous large R&D projects	Competitive selection of numerous projects with high marketability
Criteria of R&D performance evaluation	Technical success	The number of: - Papers - Patents - Technology licences	The number of: - Papers - Patents - Technology licences
Key technological achievements	TDX TiCOM DRAM	CDMA	Next-generation Internet

Note: TDX (time division exchange) is equipment for fixed-line telecommunication service. DRAM (dynamic random access memory) is one kind of semiconductor. TiCOM is the name of a medium-sized supercomputer for governmental administration. CDMA (code division multiple access) is a mobile telecommunication system.
Source: Paik, Park and Kim (2009[64]), *Knowledge transfer of government research institute: The case of ETRI in Korea*, https://doi.org/10.1504/IJTM.2009.024436.

Since then, in 2010, ETRI set up ETRI Holdings, an accelerator that identifies and matches start-ups with ETRI technologies. It also provides incubation and management services to the companies it invests capital and technologies in. Together with ETRI Holdings and its internal technology licensing office, it seeks to support start-ups with ETRI technologies to prepare them for their initial public offering (IPO) or mergers and acquisitions (M&A). Successful investments include firms such as Optella Inc., Syntekabio, Sugentech, Genesystem and Minds Lab (Business Wire, 2021[65]). Box 4.2 sets out ETRI's vision to become a leading institute in AI research and development.

Box 4.2. ETRI's vision to become a national AI research institute

Korea's ETRI is an example of a GRI that has successfully kept pace with industrial development and is preparing to become a leader in emerging technologies, particularly AI. Its strategic objective is to work toward a super-intelligent information society by developing key technologies in AI, robotics, autonomous vehicles and supercomputing.

It adopted a hybrid R&D strategy by combining research in core technologies and mission-driven research to support businesses and find solutions for societal challenges. Through open R&D strategies, including co-operation with the private sector and academia, more than 450 master's and PhD students work to develop technological innovation in AI and ICT. For instance, its Supercomputing Technology Research Centre seeks to leap forward significantly in high-performance computing with its Supreme-K project, which the MSIT funds. Furthermore, ETRI works with KISTI, 13 universities and 3 private companies for this purpose.

ETRI conducts approximately 600 projects a year, of which 30% are conducted jointly with the private sector. The institute is active in technology development, technology transfer (about 300 cases per year) and commercialisation and targets SMEs in particular. Furthermore, besides its domestic branches in Seoul, Daegu and Gwangju, it has international offices in the United States and China. Its budget primarily depends on project-based funding (85%), while a relatively low share comes from private funding. Of its 1 900 staff, around 400 are AI specialists. The remaining 1 500 staff receive training so as to render AI a basic skill and thereby make ETRI an AI powerhouse.

Source: Stakeholder interviews, 2021; ETRI (2022[66]), *Home page*, https://www.etri.re.kr/eng/main/main.etri.

4.3.2. Higher education institutions

In the early phases of industrialisation and catch-up, there was a clear division of labour between GRIs, which performed the bulk of research, and universities, whose primary task was education (Shin and Lee, 2015[67]); for an historical overview of Korean HEIs, see also (OECD, 2009[60])). During the 1960s to mid-1970s, there was a period of strong regulation limiting the number of students, with a focus of universities on teaching and a strong priority given to vocational education. Throughout the late 1970s and 1980s, regulation was relaxed and massive expansion occurred, notably through the emergence of new private universities. In the 1990s, the "first Korean academic revolution occurred, and research became a very important mission for universities, based on the 1989 'Basic Science Advancement Law'" (Kwon, 2015[68]).

In the late 1990s, the government began allocating investments into university research at a significant scale, with the Brain Korea Project launched in 1999 as a key pillar (OECD, 2009[60]). Thus, the modern Korean research and higher education system differs from many European countries and the United States in that initially, GRIs were the main research performers; the research university, as a concept, is a relatively recent phenomenon in Korea.

The rapid increase in the growth of HEIs in Korea can be partially attributed to changes introduced under the Kim Young-sam administration in 1996, which reduced the requirements for establishing universities (STEPI, 2021[62]). However, the emergence of a high number of HEIs and, therefore, departments dedicated to similar fields of research have consequentially created concerns about the efficiency of resource spending. This led the government to focus on a select number of research-based universities to streamline resources. Eventually, specialised IST universities were created under the MSIT, which allows them more leeway to be creative and flexible, e.g. in student admission, for instance, regarding creativity and other criteria that are not as much the case for universities under the Ministry of Education.

Korea faces a steep decline in the number of students due to decreasing birth rates, which dropped from 6.1 births per woman in 1960 to 1.57 in 1990 and 0.92 in 2019 (World Bank, 2022[69]). Korea currently has one of the lowest birth rates in the world and is the only OECD country with a birth rate below 1.0. As a result, the number of admitted students to Korean HEIs, which was 678 000 in 2000, is projected to fall to 373 000 in 2024, a decline of 45% over 20 years (Ministry of Education, 2021). Given that Korea has one of the highest levels of enrolment in higher education as a percentage of the school-age population, there is little room to increase the number of students given the shrinking school-age cohort.

Korean HEIs have been unevenly hit by the decline in the number of students, with local and regional universities and colleges hit harder than HEIs in metropolitan areas (Ministry of Education, 2021[70]). As a result, a growing number of HEIs is currently dealing with excess capacity (admitting fewer students than budgeted for), leading to serious financial problems, particularly for lower-tier institutions where tuition fees account for more than half of their total revenue (Chung, 2021[71]).

When it comes to industry-academia links, often referred to as the “third mission”, a legal framework has existed since the 1963 University-Industry Co-operation Act, but the real impetus was given through its revision in 2003, whereby universities were allowed to create for-profit companies based on academics’ inventions. In parallel, a Korean equivalent to the US Bayh-Dole Act, the Promotion of Technology Transfer Act, was enacted in 2000. Those initiatives led PRIs and 46 public universities to create technology licensing offices. In addition, major national R&D projects were dedicated to university-industry co-operation, including the second phase of Brain Korea, New University for regional innovation and other funds. Under these initiatives, patent filings by universities have increased 15-fold, technology transfer agreements 12-fold and royalty income 24-fold between 2003 and 2013, albeit starting from a low base (Kwon, 2015[68]).

Despite these developments, project team interviews with the private sector and university staff indicate that large firms often prefer to use their own capacities for R&D, as university research is often not considered to adequately address industry needs. Nevertheless, linkages are strong for the top-ranked research universities. For instance, a significant share of Samsung Electronics researchers graduated from KAIST, and a significant portion of their research funding comes from industry, as discussed in the following section. Similarly, Seoul National University and other universities work on problem-solving solutions with SMEs and, in the case of SNU, together with Samsung, train human resources in AI.

4.4. Funding of government research institutes and higher education institutions

4.4.1. Government research institutes

Both the financing of GRIs as well as total government expenditure on R&D (GOVERD)[1] have been increasing significantly in the last decades. However, a recent trend shows that the financing of GRIs has stagnated at about 0.15-0.16% of GDP. Furthermore, the share of GRIs in GOVERD has also decreased; while 42% of the GOVERD was directed towards GRIs in 2006, indicating that GRIs were the major recipient of the government’s R&D investment, in 2020, this share shrunk to 33% in 2020 (KISTEP, 2020[72]). This contrasts with higher education expenditure on R&D (HERD), which continuously rose to 0.43% of GDP in 2020.

Funding sources for GRIs can be divided into three categories: government block funding from the central government and the municipalities; project-based funding (otherwise known as “project-based system”, PBS) from public clients; and private funding. For the entire period, most of the funding came from public sources. In 2021, more than 83% of the total funding originated from the government, of which most came from government block grants. The amount of funding received from the private sector remains low, albeit gradually increasing. This indicates a rise in the number of collaborative projects between GRIs and the business sector, to be explained in detail in the following sections.

Table 4.8 shows the five most funded GRIs in 2021. The five institutes alone received almost half (47%) of the total GRI funding. ETRI is in the lead with USD 521 million. Interestingly, the share of government block funding is relatively low. The major source of funding for ETRI is PBS.

Table 4.8. Split of funding for Korea's top-five most funded government research institutes

In KRW billions

GRI	Total	Government contribution (%)	PBS (%)	Private contribution (%)
Total (25 GRIs)	5 508	4 583 (83%)	3 067 (56%)	533 (10%)
Electronics and Telecommunications Research Institute (ETRI)	674	563 (84%)	489 (73%)	23 (3%)
Korea Atomic Energy Research Institute (KAERI)	615	351 (57%)	444 (72%)	241 (39%)
Korea Aerospace Research Institute (KARI)	503	478 (95%)	382 (76%)	16 (3%)
Korea Institute of Science and Technology (KIST)	405	358 (88%)	195 (48%)	27 (7%)
Korea Institute of Industrial Technology (KITECH)	400	345 (86%)	256 (64%)	29 (7%)

Source: (Ministry of Science and ICT, 2022[73]).

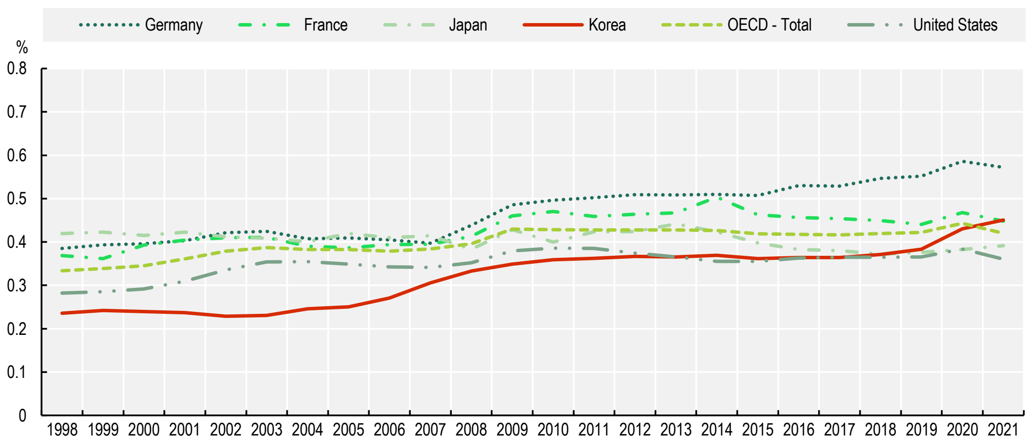
In 1996, the funding mechanism for the GRIs was reformed. The reform introduced a competitive element into GRI funding. However, it also meant that the continuity of research was no longer assured. It also changed the incentives of the GRIs, encouraging them to focus on maximising not only their income from projects but also the number of projects rather than the overall goal of development. Amid concern about duplication of R&D and worries about the efficiency of the GRIs, the autonomous, Battelle-derived model was abandoned and replaced with the PBS, in which institutional GRI research funding was awarded for the performance of specific projects negotiated between the GRI and the government. At the same time, other competitive project funding was also available from the government. This reform reduced the autonomy of the GRIs in the sense of restricting the freedom to develop long-term priorities for the purpose of competitiveness and to serve societal needs as the competitive project-based system incentivised short-term focus. The reliance on funding earmarked for projects with short-term horizons means less ability to independently shape a long-term research orientation based on basic science objectives with a long time horizon.

4.4.2. Higher education institutions

The increase in funding for universities in Korea has been one of the largest among OECD countries. However, its share is lower than that of other leading innovators in the OECD, such as Germany and Japan (Figure 4.18).

Figure 4.18. Higher education expenditure on R&D in Korea and selected countries, 1998-2021

As a percentage of GDP



Note: OECD data are estimated. Difference in methodology for the United States.
Source: OECD (2022[74]), *Main Science and Technology Indicators* (database), oe.cd/msti, May 2022.

Since 2009, the government has funded around 80% of R&D expenditure in universities, having increased from less than 50% in 1997 (OECD, 2022[75]). In 2021, ministries funded 74,745 projects with an average value of around 350 million KRW, which would be equivalent to about EUR 250,000 each (Ministry of Science and ICT and KISTEP, 2022[76]). Nevertheless, the value in terms of serving strategic priorities or promoting excellence in and impact of universities seems uncertain. . Table 4.9 shows the funding allocations to programmes and projects for selected ministries.

In 2020, research funding allocated to HEIs represented 0.43% of GDP in Korea (OECD, 2022[74]), in line with the OECD average of 0.44%, lagging countries such as Austria, Canada, Denmark, Finland, Norway and Sweden who spent more than 0.70% of GDP on HERD, but higher than the United States at 0.39%. Three-quarters of this funding originated from the central government. Another quarter came from domestic private funding. Compared to benchmarking countries within the OECD, the share of central government in the funding is over-represented. For instance, in the United States, USD 86 billion worth of research funding was allocated to HERD expenditure, where 53% originated from the federal government (National Science Foundation, 2021[77]). In France, on the other hand, USD 21 billion was spent on HERD, and 60% originated from the central government (Minister of Higher Education, 2021[78]). Table 4.10 shows the overall split of research funding and the average funding per researcher by different types of universities in Korea.

Table 4.9. Korea's university funding by ministry, 2020-21

	2020			2021		
	No. of programmes	No. of projects	Expenditure (KRW hundred millions)	No. of programmes	No. of projects	Expenditure (KRW hundred millions)
Ministry of Science and ICT	283	22 370	77 137	303	25 041	83 472
Ministry of Education	23	18 900	21 646	24	15 957	23 068
Ministry of Land, Infrastructure and Transport	49	577	5 030	71	731	5 979

Ministry of Trade, Industry and Energy	185	5 413	40 113	198	5 815	46 451
Ministry of Agriculture, Food and Rural Affairs	31	1 668	2 076	26	1 616	2 281
Rural Development Administration	57	4 600	6 869	58	4 525	7 705
Ministry of Health and Welfare	69	2 448	6 433	62	2 355	5 768
Ministry of SMEs and Startups	37	10 212	14 046	40	10 380	16 650
Defense Acquisition Program Administration	8	583	37 715	9	521	38 497

Source: (Ministry of Science and ICT and KISTEP, 2022[76]).

Table 4.10. Korea's higher education institution R&D expenditure and researchers by university type, 2021

Type	Percentage	Expenditure (USD millions)	Researcher	Expenditure per researcher (USD thousands)
IST	9.0%	499	1 465	341
Private	59.5%	3 284	54 338	60
Public	7.2%	399	7 262	55
Flagship	24.3%	1 343	11 748	114
Total	100.0%	5 525	74 813	115

Note: IST universities include DGIST, GIST, KAIST and UNIST. Expenditure refers to project-based expenditure (PBS).
Source: OECD analysis based on NRF statistics, August 2022.

In absolute terms, private universities are the biggest recipient of research expenditure, with USD 3.3 billion, accounting for almost 60% of the total research spending. A quarter of the research expenditure is directed towards flagship universities, followed by IST universities and public universities.

Expenditure per researcher – total expenditure divided by the number of researchers in the institution – is an important indicator to distinguish universities focused on research activities. This indicator is highly correlated with the university's ratio of graduate students and its ratio of STEM-related courses, with the correlation value of 0.95 and 0.7, respectively.[17] In other words, a university with relatively more graduate students and relatively more STEM-related courses is associated with higher expenditure per researcher than other universities.

In expenditure per researcher, the IST universities are the biggest recipients. This is because the IST universities were conceived as research universities at the outset and focused on STEM disciplines, requiring higher financing levels. As a result, a researcher in IST universities receives around USD 390 000, which is six times higher than the private university average. However, this does not make private universities less important in funding distribution. For instance, the top-ten private universities see 70% more expenditure per researcher than the top-ten flagship universities. This highlights the importance of private universities in Korea's R&D, particularly from the PBS.

Impact of funding on research output

Efforts are made worldwide to apply scientometric models to confirm the correlation between research funding and scientific excellence. One example is the CWTS Leiden Ranking, provided by Leiden University in the Netherlands. Along with different indicators, CWTS provides "PP(top10%)", which is the proportion of a university's publications that, compared with other publications in the same field and the same year, belongs to the top 10% most frequently cited.

Using the above-mentioned indicator, along with additional data on publication, regression models were built to establish a correlation between funding and scientific excellence. To find whether funding has more impact on the quantity or quality of research, three regressions were conducted with three different dependent variables: 1) PP(top10%); 2) publications per researcher; and 3) the ratio of top 10% cited per researcher. The last variable was obtained by multiplying the PP(top10%) score by the average number of publications per researcher for each institution ().

It is possible to observe an established correlation between publications per researcher and funding with an R^2 of 0.83. When it comes to the relationship between funding and the quality of research, the correlation is visible but to a lesser extent with respect to quantity. Both PP(top 10%) and the ratio of top 10% cited per researcher showed a positive correlation with expenditure per researcher. Nonetheless, Figure 4.19 shows correlation and not causation, and additional variables, such as specialisation in particular fields which differ in cost intensity, should be considered when identifying the drivers of research quality.

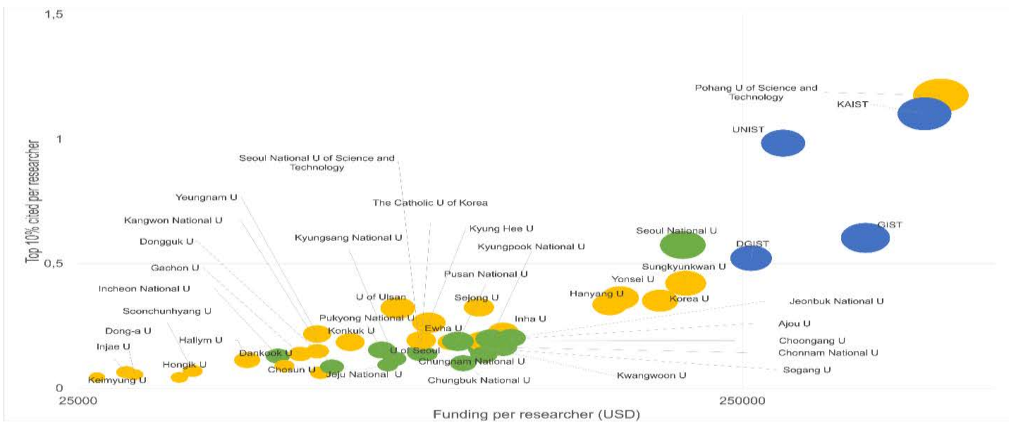
On closer view of the results, universities are in the lead with the highest funding per researcher, and their publications have the highest percentage of being classified among the top 10% cited. They also tend to excel in research quantity and have the highest average number of publications per faculty. This is not a surprising result, as IST universities have been dedicated to scientific research since their foundation, and their research activities focus entirely on STEM fields. The only non-IST universities with comparable achievements are SNU and POSTECH, with the latter being a private university. These universities belong to the "research-active" cluster, as defined by the classification previously discussed in the Clustering section.

On the other hand, flagship universities other than SNU show lower performance in research excellence, suggesting that funding directed towards flagship universities is less efficient in increasing research quality. One should also note that while private universities are mostly above the fitted line, the flagship universities are all below the fit – suggesting that those universities seem to be somewhat less effective in achieving quality output at equivalent levels of funding. One potential factor in explaining this is that the flagship universities are often located outside Seoul, which makes them less attractive to students, researchers and professors.

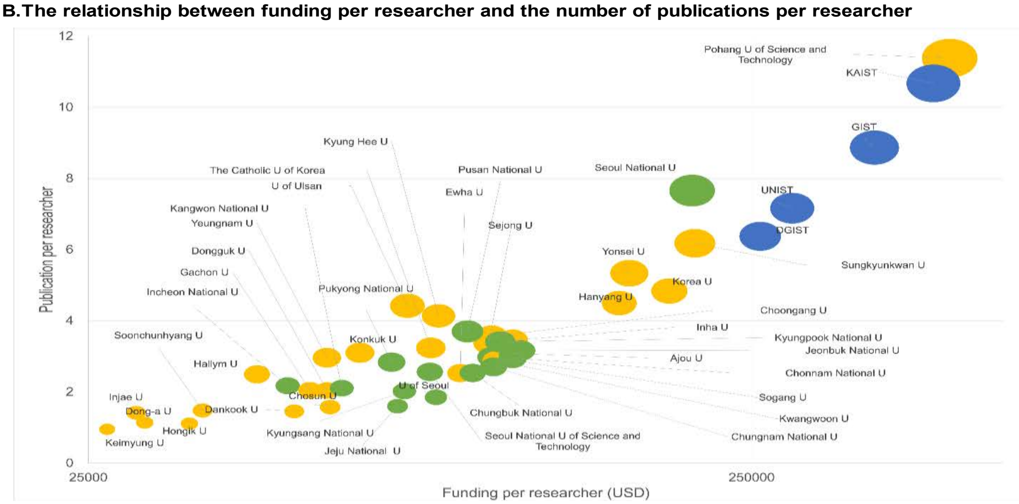
Finally, it should be noted that UNIST is an outlier, with outstanding results significantly better than even its high level of financing would warrant. This is probably due to specific internal rules that encourage top-quality publications. It became apparent from stakeholder interviews that from the outset of its establishment in 2007, UNIST has made research quality, as measured by the number of publications in the top 5%-cited journals, a criterion for the evaluation of professors, while standard practice in Korea had been to focus on the number of publications. Furthermore, great importance was placed on internationalisation, and as such, whether and the extent to which professors spoke at international events mattered for tenure at UNIST. In addition, around 11% of professors are of foreign nationality. UNIST receives around KRW 80 billion in annual block funding from the MSIT, most of which is earmarked for education, with around 5% for research, in line with government strategies. On top of this, UNIST has a long-term R&D fund, which it presides over autonomously. Around KRW 150 billion is received through project-based funding, most of which comes from the government and, to a lesser extent, from industry. Sometimes, the MSIT will grant projects to UNIST, but mostly, it is professors who are fairly autonomous in choosing their projects with the condition that they are in line with the overall government strategies. Finally, around KRW 5 billion is earmarked for internal promotion purposes.

Figure 4.19. Funding is correlated with research quantity and quality in Korean universities

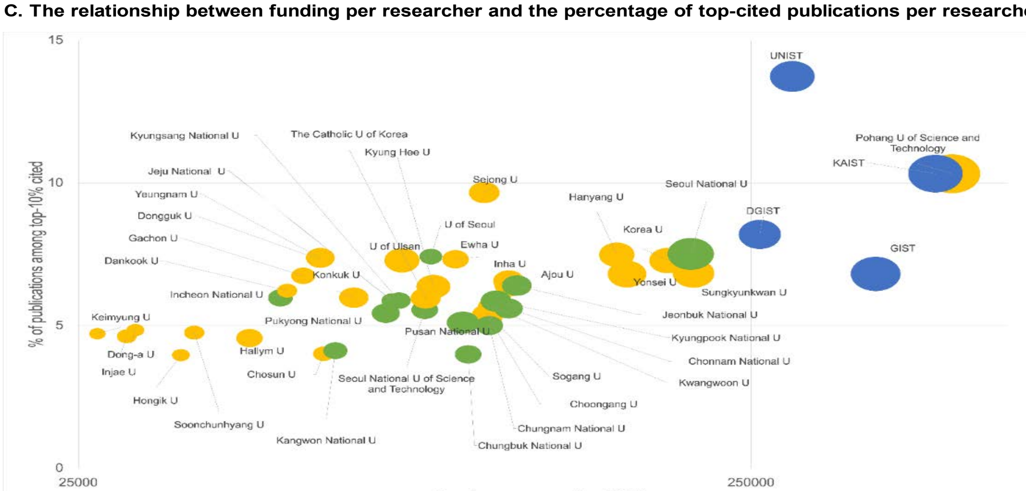
A. The relationship between funding per researcher and the percentage of top-cited publications



B. The relationship between funding per researcher and the number of publications per researcher



C. The relationship between funding per researcher and the percentage of top-cited publications per researcher



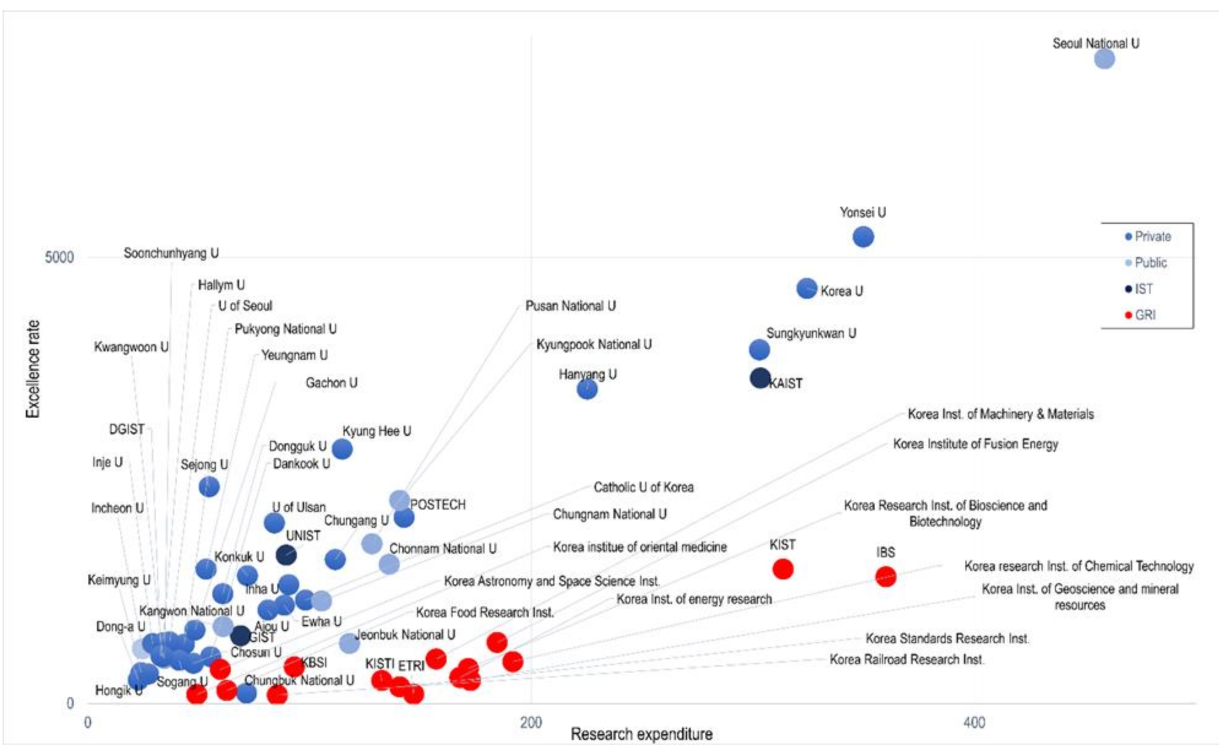
Note: The colours blue, green and yellow represent Institutes of Science and Technology, public and private universities, respectively. NRF data are based on a survey led by NRF with individual researchers, which captures all R&D funding received by researchers, including, for example, projects financed by the Ministry of Defense.
Source: OECD analysis based on NRF statistics, August 2022.

To assess and compare the effect of funding in the research activities of the HEIs and the GRIs, 58 Korean institutions ranked by their research excellence (Exc)[18] in SCImago Institutions Rankings were analysed (Figure 4.20). Of the 58 institutions, 42 were HEIs, and 16 were research institutes, of which 15 can be identified as GRIs. Similarly to the above analysis, a positive correlation between research expenditure and excellence was observed for HEIs and GRIs.

For a given level of funding, HEIs had higher research excellence than research institutes. SNU showed an outstanding number of publications that belongs to the 10% most cited, followed by prestigious private universities such as Yonsei University and Korea University. While IST universities excelled at the Leiden Ranking analysed above, they do not stand out in the SCImago Ranking. This may be due to IST universities' relatively small size and lack of humanities-related majors.

Among the research institutes, IBS and KIST had the highest excellence rate. IBS, a research institute under MSIT but not under NST, had the highest expenditure. Over 50% of the IBS budget is dedicated to the Rare Isotope Science Project, which aims to build a heavy ion accelerator and is not very conducive to a high number of publications. This helps explain why other GRIs, such as KIST or the KFE, showed greater research excellence and efficiency.

Figure 4.20. Research excellence increases with expenditure in Korean higher education institutions and research institutes

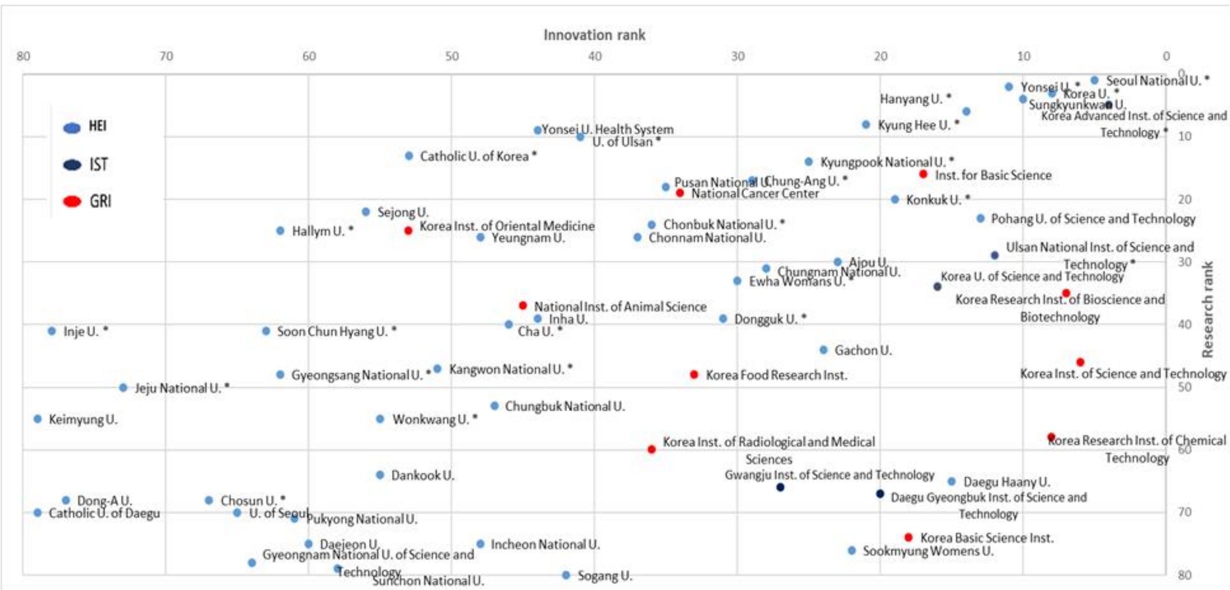


Note: On the vertical axis, research excellence is measured by "the amount of an institution's scientific output that is included in the top 10% of the most cited papers in their respective scientific fields." The horizontal axis is the research expenditure of each institution in USD millions. NRF data are based on a survey led by NRF with individual researchers, which captures all R&D funding received by researchers, including, for example, projects financed by the Ministry of Defense.

Source: OECD analysis based on NRF statistics, August 2022; SCImago Institutions Rankings (n.d.[79]), *Ranking methodology*, https://www.scimagoir.com/methodology.php; 2022 SCImago excellence rate (2017-20).

Overall, research expenditure is a statistically significant factor in explaining the research excellence for HEIs and GRIs. However, the model used here indicates that the research output of research institutes was lower than that of universities. This may suggest that research institutes are smaller in size or that their roles and responsibilities (R&Rs) do not prioritise the publication of scientific papers. Figure 4.21 shows the innovation and research performance of top HEIs and GRIs. It indicates that some GRIs rank high in terms of innovation but relatively low for research. The top universities perform best in terms of both innovation and research ranks.

Figure 4.21. Innovation and research SCImago rankings of Korean higher education institutions and research institutes, 2022



Note: See [Methodology (scimagoir.com)](https://www.scimagoir.com/methodology.php) for the criteria and methodology of the research and innovation ranking.
Source: OECD analysis based on SCImago Institutions Rankings (n.d.[79]), *Ranking methodology*, https://www.scimagoir.com/methodology.php, 2022.

4.5. Governance of government research institutes and higher education institutions

The main policy concerns with the research sector are achieving academic excellence (including in basic science) and return on investment, for instance, to foster breakthrough innovation and research which serves long-term societal needs. Accordingly, various adjustments to institutional governance have been attempted, including competitive financing of research in the form of competitive grant allocation. A notable recent development has been the introduction of the National Research and Development Innovation Act ("Innovation Act"), which proposes many positive changes in terms of research autonomy. Nevertheless, further efforts would be needed to encourage creative, long-term, high-risk and high-return research. Previously, most project evaluations were annual with very strict numerical objectives that needed to be met for evaluation and promotion purposes and left little space for developing creative, long-term "moonshot" types of basic research (Kim, 2022[80]) (Box 4.3). The Innovation Act, enacted in January 2021 with the purpose of innovating the implementation system of national R&D programmes and fostering an autonomous and responsible research environment, entails inter-ministerial joint standards for R&D and abolished project-based annual evaluations and replaced these with stage evaluations. In addition, there has been a shift from quantitative to qualitative evaluation, with the latter comprising more than 50% of metrics. Nevertheless, short-term horizons of projects can come at the cost of high-risk and high-return research: 48% of projects last three years or less.

Box 4.3. Fostering high-risk, high-impact research

The Moonshot R&D programme in Japan

The Cabinet Office launched the Japanese “Moonshot” programme to promote high-risk, high-impact R&D to find solutions to the significant challenges Japan faces, such as drastic population ageing and climate change.

In 2013, the Japanese government introduced the ImPACT programme, a five-year R&D programme aimed at encouraging S&T solutions to rising societal challenges by recruiting researchers with disruptive and ambitious research ideas. While successful, the programme, in part, brought forward projects with only limited disruptive potential. The Japanese government recognised that governments in the European Union and the United States supported high-risk, high-impact R&D on a significantly larger scale and, furthermore, were encouraged to recruit top researchers internationally to leverage global expertise.

Consequently, the Cabinet Office established the Moonshot programme in 2019, when the ImPACT programme ended. This new mission-driven programme seeks to foster revolutionary research concepts that go beyond being merely incremental extensions of already existing technologies, hence “moonshots”. The intention is to maximise Japan’s basic research capabilities to develop disruptive research projects without being held back by the possibility of failure. For this programme, the Council of Science, Technology and Innovation, which was granted more authority and a wider mandate, thus enabling it more bargaining power than ministries, formulated nine goals responding to pressing societal challenges and how S&T can augment the future of humanity. The goals are meant to be easily comprehensible and recognisable for society, such as the “realisation of a society in which human beings can be free from limitations of body, brain, space and time by 2050” and the “realisation of ultra-early disease prediction and intervention by 2050”. It was launched in 2019 with almost USD 900 million earmarked for a period of ten years from the start of the research. The duration of the projects and whether they will be continued is contingent on frequent evaluation procedures.

Evaluation criteria for high-risk, high-reward (HRHR) research

Reaching the international knowledge frontier requires the funding of science with significant risk, as many funded projects will fail while few will result in ground-breaking findings with revolutionary impact (Machado, 2021[81]). However, extensive reliance on traditional indicators for evaluating programmes and research outputs, such as Journal Impact Factors (JIFs) and H-indexes, has been proven to be a possible source of risk aversion in funding science.

Several attributes of knowledge are particularly characteristic of HRHR research, namely, basicness, which is at the core of basic research, i.e. theoretical discovery as a result of research on the foundation of a phenomenon without specified application or use; generality, which indicates the breadth of fields a scientific finding can be applied to; and novelty, i.e. a discovery highly distinguishable from the status quo.

In particular, scientific novelty is critical, as extraordinarily novel findings are associated with scientific breakthroughs and high impact. Some suggested indicators measuring novelty include new or uncommon pairwise combinations of citations in a scientific article, indicating new knowledge combinations and a higher extent of novelty. Other indicators for novelty may be given by the average age of keywords in abstracts with new or younger words suggesting higher novelty.

Machado’s (2021[81]) analysis includes the development of a novelty indicator based on new and uncommon citation pairs, implying that a pair of citations is used in an article for the first time together. He finds that several factors significantly drive novelty, including the share of top-cited publications, business expenditure on R&D, international collaborations and higher overall R&D spending. However, in a more robust statistical analysis, the latter two were not significant. It is suggested that the introduced novelty indicator may be a relevant complement to traditional indicators aiming to evaluate science funding.

Korea's Alchemist project

In 2019, the Korean government launched the Alchemist project, which seeks to foster disruptive innovation with the potential to bring about transformative change to industries in 10-20 years. A total budget of KRW 414 billion (USD 290 million) is earmarked to support the project for ten years, of which KRW 374 billion comes from the government while the rest comes from private sources. Universities, businesses and GRIs are eligible to submit proposals that are assessed based on the degree of innovativeness, industrial impact, global leadership, impact on society and human life and differentiation, i.e. the degree to which it holds independent technical value. Some of the new thematic areas of the project are reverse ageing, Hypervision metaverse and biomimetics carbon recycling.

Korea Advanced Research Programme Accelerator (KARPA)

In 2020, MSIT launched the Korea Advanced Research Programme Accelerator (KARPA) which was meant to emulate the US DARPA model to stimulate and promote breakthrough innovation. It seeks to foster inter-ministerial co-ordination and to bring solutions to national problems as well as promote innovation-leading industries. A more detailed analysis of the programme is given in Chapter 5.

Source: Japan Science and Technology Agency (2022[82]), *The basic approach for the Moonshot Research and Development Program*, https://www.jst.go.jp/moonshot/en/about.html; OECD (2022[83]), *OECD STIP Compass*, https://stip.oecd.org/moip/countries/japan; Machado (2021[81]), "Quantitative indicators for high-risk/high-reward research", https://doi.org/10.1787/675cbef6-en; KISTEP (2020[84]), *Launching of K-DARPA: Aspiring to be Korea's DARPA*, https://www.kistep.re.kr/board.es?mid=a20501000000&bid=0051&act=view&list_no=37139&tag=&nPage=5.

4.5.1. Government research institutes

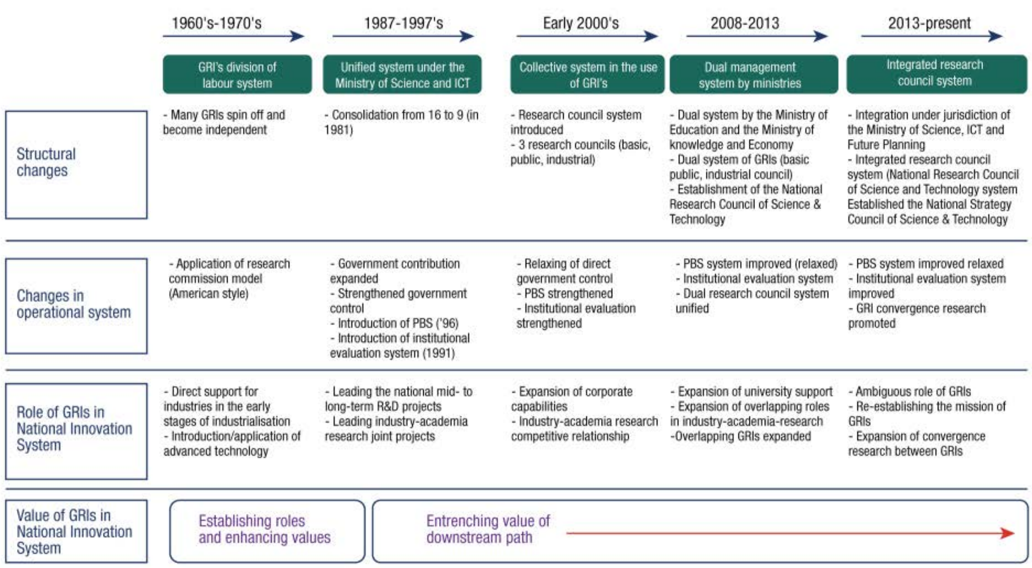
In the 1980s, in response to growing criticism of inefficiency, overlaps and failure to meet industry needs, 19 GRIs that had previously been under the authority of various ministries were consolidated into 9 under the jurisdiction of the Ministry of Science and Technology (STEPI, 2021[62]). The government also provided funding for GRIs to collaborate more closely with industry in the hope that that would increase their relevance and impact (OECD, 2009[60]). However, criticism of the GRIs' efficiency and performance continued throughout the 1980s and 1990s. Eventually, it led to the establishment of the PBS in 1996, effectively forcing GRIs to compete for funding rather than benefitting from guaranteed block funding. The Act on the Establishment, Operation, and Fostering of Government-funded Science and Technology Research Institutes enacted in 1999 led to the creation of research councils and reverted the management of GRIs back to a multi-ministry structure (Figure 4.22).

In the past two decades, the relative importance of the GRIs has continuously declined – as reflected in their share of total R&D expenditure – as the research capacity of universities and industry has grown. In its 2009 innovation review of Korea, the OECD cautioned with regard to GRIs, "[T]he main problem – stretching back perhaps 30 years – has been a lack of consensus on the role that the GRIs should play in the innovation system", though it acknowledged that this problem was not uncommon in countries with similar industrial research institute structures and that the role of GRIs becomes "less clear-cut" as an innovation system evolves and industry's own research capacities strengthen (OECD, 2009[60]).

In their early days, the GRIs' functions often focused on acquiring technologies from abroad and implanting them in Korea, partly through technical services and training. However, as government R&D funding rose, the GRIs took on increasingly R&D-focused roles. In some cases, such as metrology, R&D activities were transferred from existing government labs into the new GRIs.

By the 1980s, companies – especially the chaebol – were doing increasing amounts of intra-mural R&D, and it was less and less clear that they needed GRIs to substitute for this. As mentioned above, 19 GRIs were consolidated into 9 and placed under the then Ministry of Science and Technology as industry increasingly generated and acquired its own technologies. The GRIs continued to do large R&D projects to support national competitiveness, but the industry's capacity for research was increasing. The number of in-house corporate R&D labs rose from 46 in 1979 to 183 in 1985, so the role of the GRIs in relation to industry clearly needed to change to adapt to industrial development.

Figure 4.22. The evolution of Korea's government research institutes, 1960s-present



Source: STEPI (2021[62]), *Background Paper - OECD Reviews of Innovation Policy: Korea 2021*.

The NST was founded in 2014 when two research councils merged, so as to streamline the functions of GRIs by fostering their co-operation and evaluating their research performance. It initiated the Convergence Research Programme in 2014, which aims to streamline and accomplish large-scale research work in GRIs; contribute to finding solutions to societal challenges and technical issues faced by industry; and develop leading technologies (National Research Council of Science & Technology, 2022[85]).

4.5.2. Higher education institutions

In the first decade of the 21st century, government funding to universities increasingly focused on special purpose, project and performance-based funding allocated in competition (Han et al., 2018[86]). The Korean government has sought to promote examples of objectives or special purposes through earmarked funding, including promoting excellence, capacity building, specialisation, industry-academia collaboration, innovation and internationalisation (Han et al., 2018[86]) (STEPI, 2021[62]). Han et al. provide an overview of such programmes offered by the Ministry of Education (see below). The Ministry of Education relies strongly on quantitative (quantifiable) indicators and criteria both for assessing applications and evaluating programmes. However, these indicators say relatively little about the long-term impact, direction of change or strategic development. Furthermore, they might be counter-productive to the desired outcomes by steering behaviour towards short-term rent-seeking and designing and reporting indicators and plans to match call texts rather than long-term impact and change (Han et al., 2018[86]).

Han et al. identify several issues with government HEI programmes, which have also been confirmed in stakeholder interviews. Their traditionally rather interventionist and top-down nature appears to undermine their acceptance in the larger stakeholder community. They also disincentivise diversity and universities' ability to act strategically and differentiate themselves.[19]

> *For individual universities to win the financial support projects secured by the government, it is in the best interest of each university to plan and carry out as many programmes as possible. […] the low differentiation in terms of the purpose and content of support between the projects is also pointed out as the culprit weakening universities' bid toward specialization. (Han et al., 2018, p. 94[86])*

They also point to redundancies and overlap in policies, with new governments eager to introduce new measures, and a lack of coherence, consistency and co-ordination of HEI policies: "The goals of recent programmes have been mainly biased toward solving short-term socio-economic problems, such as low employment ratio and working on new industrial innovation, rather than enhancing the long-term standards of the system." This point echoes the analysis by Byun (2009) and was also made by the OECD (OECD, 2014[87]) which identified "policy activism" – i.e. the tendency to introduce numerous and rapidly changing programmes and policies in response to deep-rooted structural or institutional shortcomings – as a problem of Korean policies more generally. Policy activism and inconsistencies might also partially explain what observers perceive to be the passive or reactive natures of Korean universities when it comes to institutional renewal.

Table 4.11 presents an overview of programmes the government launched, the provided budget and their duration.

Table 4.11. Overview of Korea's major university-supporting programmes

Name	Purpose	Budget size KRW billions	Periods	Beneficiary
CORE	Strengthening human resources capacity and innovation in universities Establishing an infrastructure for humanities education and research, training talented human resources	60 (2016)	3 years (2016-18) (2+1)	University
PRIME	Improvement of university constitution centred on social demand (quantitative + qualitative) Strengthening student career capacity and eliminating mismatch of personnel	201.2 (2016)	3 years (2016-18)	University
CK	Characterisation of comparative advantage areas based on community demand Strengthening university competitiveness and supporting mutual growth with local communities	245.6 (2014) CK-I: 191 CK-II: 54.6	5 years (2014-18) (2+3)	Programme
SCK	Fostering professional colleges as centres of higher vocational education	269.2 (2014)	5 years (2014-18) (2+3)	Programme
BK21+	Developing world-class graduate schools and excellent researchers Enhancing the quality of education and research in domestic universities	252.6 (2013)	7 years (2013-19)	Programme
LINC+ [LINC]	Supporting the cultivation of custom-made talent reflecting industry-leading university development and social demand	238.3 (2017) [LINC 170 (2012)]	5 years (2017-21) (2+3) [5 years (2012-16) (2+3)]	University
ACE+ [ACE]	Well-taught college, fostering leading undergraduate university Creation and diffusion of leading model	73.5 (2017) [30 (2010)][23]	4 years (2017-20) (2+2) [3 years (2010-12 (2+1)]	University

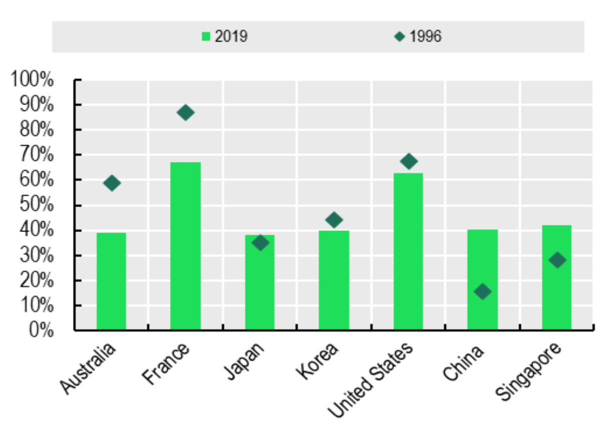
Name	Purpose	Budget size KRW billions	Periods	Beneficiary
	for advanced education in undergraduate education			
LC	Establishing an education system for lifelong learners	30 (2016)	1 year (2016)	University
PoINT	Establishing an innovation base and proprietary development model of the National University Collaboration and function restructuring, such as sharing of resources between universities and joint education curriculum	19.5	2 years (2017-18) (1+1)	University
BRIDGE+ [BRIDGE]	Enhancement of universal creative asset utilisation function Strengthening capacity utilisation of national technology, creation of technology-based new industry	12.5 (2018) [15 (2015)]	5 years (2018-2022) (2+3) [3 years (2015-17)]	University
WE-UP	Reorganisation of a female-friendly engineering education system Cultivation of female specialists who customise industrial demand	5 (2016)	3 years (2016-18)	Programme or consortium

Source: Han et al. (2018[86]), *An Analysis of Higher Education Policy: The Case of Government-Supported University Programs in South Korea*, https://doi.org/10.7545/ajip.2018.7.2.364.

Furthermore, over recent decades, governments in Asia have recognised the importance for HEIs to engage in basic research to spur disruptive innovation and have, therefore, increased funding to that effect. However, the share of R&D in basic science in Korea declined between 1996 and 2018 relative to applied research and experimental development, while it strongly increased in China and Singapore in the same period (Figure 4.23). In 2016, in response to a petition by basic scientists to the National Assembly demanding an increase in funding for basic research and a higher degree of research autonomy, the Korean government pledged the doubling of bottom-up basic research funding to USD 2.2 billion between 2017 and 2022. Although other OECD countries, such as Australia and France, have shown the same declining trend, the decrease occurred from higher initial percentages, leaving Korea as having one of the lowest shares of basic science R&D by the higher education sector as a percentage of its total R&D expenditure (OECD, 2022[88]). High national demand for applied R&D has contributed to universities participating in such research.

Figure 4.23. Expenditure on basic R&D by the higher education sector in Korea and selected countries, 1996 and 2019

As a percentage of total higher education expenditure on R&D



Note: For Australia, 2018 data are used.
Source: OECD (2022[89]), *Research and Development Statistics (RDS)* (database), oe.cd/rds, September 2022.

4.6. Research infrastructures

Korea has invested significant resources in the establishment of research infrastructures and equipment. Equally, to improve their efficiency and management, several platforms have been launched to enhance the co-ordination across the public research system.

The government has developed two roadmaps for national large research facilities (NLRFs) whose purpose is to provide a long-term oriented strategy and support system to ensure Korea's position as a leading country in S&T (Roadmap 1) and in large research facilities, to pioneer the creative economy (Roadmap 2), knowledge-based economic activities to foster creative and cultural sectors. Several characteristics of these large research facilities are the networking effects of primary scientific and technological research and their independence in terms of management and operations while being regularly evaluated by supervising bodies. Large research facilities also have their own operating and processing personnel and research staff, often engaged in co-operation beyond regional and national borders. Other typical characteristics are their mostly open accessibility to external users and national rather than ministry-level financing (Ministry of Science and ICT, 2019[90]).

The benefits of large research facilities are multi-fold (Michalowski, 2014[91]). They include increased co-operation domestically and internationally, facilitating knowledge exchange and attracting foreign talent while preventing the brain drain of highly skilled locals. Furthermore, associated research groups are often involved in pioneering research, resulting in fundamental breakthrough innovations which can possibly create new industries. As described earlier in this chapter, Korea's participation in large international infrastructures, such as CERN, ITER, EMBL, etc., indicates the government's awareness of these benefits for the research community. In addition, NLRFs contribute to economic and social development by creating jobs, training scientists and students, and fulfilling their duty to engage in research to address prevailing and arising societal challenges.

The Korean government launched its NLRF Roadmap 1 in 2010 to assist 69 facilities with establishment costs ranging from KRW 5 billion to KRW 750 billion (USD 3.5-530 million) per listing. It was established by the previous Ministry of Education, Science and Technology and focused on five core areas related to the S&T Basic Plan. The updated NLRF Roadmap 2 has a somewhat larger scope by focusing on 12 "megatechnics" areas[20] and supporting 13 major research facilities, each costing over KRW 50 billion. While the validity reviews of Roadmap 1 are based on researcher demand surveys, those of Roadmap 2 additionally entail a factual survey, performance analysis and environmental change (Ministry of Science and ICT, 2019[90], STEPI, 2021[62]).. compares major research infrastructures and shows that Korean investment is 0.18% of GDP, somewhat lower than other countries. It should be noted, however, that Korea started several years later than the European Union and the United States. Still, comparing it within Asia, Japan and China launched their respective infrastructures around the same time and allocated considerably higher investments relative to GDP.

Table 4.12. Korea's national large research facilities in comparison with selected benchmarking initiatives

Country	Initiative	Year	No. of facilities	Total investment (as % of GDP)
European Union	European Roadmap for Research Infrastructures (ESFRI)	2006	35	0.37
		2008	44	
		2010	38	
	ASTRONET Infrastructure Roadmap	2008	25	
United States	Facilities for the Future of Science	2003	28	0.28
		2007	28	
	Facility Plan	2005	25	
		2008	19	

Country	Initiative	Year	No. of facilities	Total investment (as % of GDP)
China	Large Research Infrastructure Development in China: A Roadmap to 2050	2011	34	0.33
Japan	Large Research Infrastructure Plan	2010	43	0.48
Korea	National Large Research Facilities Roadmap (NLRF) 1	2010	69	0.18 (NLRF 1)
	National Large Research Facilities Roadmap (NLRF) 2	2012	13	0.27 (NLRF 1+2)

Note: The investment calculation is based on the 2017 constant USD (PPP) for GDP in 2021. The number of facilities refers to those supported in the respective year (not the total).

Source: OECD calculations based on Ministry of Science and ICT (2019[90]), *National Large Research Facilities Roadmap*, https://publicadministration.un.org/unpsa/Portals/0/UNPSA_Submitted_Docs/2019/d4164970-f5aa-4c09-9588-23c3fa89f0ca/2020%20UNPSA_ZEUS_National_Roadmap_26112019_093032_de461911-3adc-461a-9e2f-53e310d84ca3.pdf.

In addition to the establishment of research equipment facilities, the sharing of such also has wide-reaching benefits for the research community. In the past, the co-utilisation of research equipment in research projects in Korea has been low because it has focused R&D investment capabilities on securing research institutes' capabilities. However, after the policy shift to utilisation-oriented rather than input-led investments in 2008, the overall demand for shared research equipment access in Korea increased, and the government launched digital platforms to that effect. The Zone for Equipment Utilisation Service (ZEUS) platform allows researchers to find and reserve R&D facilities and equipment nationwide. It is operated by the National Research Facilities and Equipment Centre (NFEC) in the KBSI and interconnects equipment and facilities funded by the government while providing researchers from the private and public sectors with the possibility to reserve these. Around 5 300 reservations are undertaken daily, and the platform enables researchers to exchange experiences and feedback regarding the equipment and facilities. In addition to the core platform, four complementary sites fulfil different objectives, such as strategic investment, training of engineers, international collaboration, and research and infrastructure linkage.

Due to these policies, the number of joint use of research institutes has significantly increased (from 2 008 cases in 2013 to 128 112 cases in 2021), and the number of joint utilisation facilities that serve those underprivileged in R&D is increasing (from 52 cases in 2011 to 438 cases in 2021). Reasons for low co-utilisation are multi-fold and notably include the lack of awareness of the role and function of public goods, as well as legal ownership and responsibility of the research site. Furthermore, some noted that policies have been developed top-down and have not adequately considered the researchers' perspectives and incentives to use or share equipment. Professors at universities, for instance, have placed little emphasis and importance on the co-utilisation of research equipment, partly due to low recognition and low awareness of the need to make it available to others, resulting in protective ownership. Other factors impede the co-utilisation of equipment, such as a lack of plans to systematically organise the use of equipment or difficulties in accounting separately for joint use in the budget (Yi, 2016[92]). Promoting various policy activities for the joint use of equipment, such as completing the equipment management operating system for joint use, education to improve awareness, and budget support at the national level, could help in this regard.

4.7. Knowledge flows between higher education, government research institutes and business

4.7.1. An overview of international knowledge flows

Organising knowledge flows between academia and business is key to realising the full value to society of the knowledge created by scientific research to leverage it in high-value-added products and services. This is becoming even more important in the context of leveraging STI as a contribution to the resolution of societal challenges, where civil society organisations are also important stakeholders (please refer to Chapters 2 and 5 for a more comprehensive discussion of societal challenges).

The facilitation of such knowledge flows is one of the large challenges faced by many OECD countries and other advanced economies. Whether in PRIs or HEIs, academics often focus on addressing fundamental scientific issues, and their main objective is to advance the knowledge frontier and publish the results of their research in prestigious scientific journals. The diffusion and application of knowledge in the economy is rarely an objective that academics would spontaneously pursue unless significant incentives are created. Similarly, the business sector would rarely reach out to academia to help resolve some issues and satisfy the needs of their customers.

Large legacy barriers exist between the different communities, with different educational backgrounds, value systems, time horizons and social circles. For example, while business people will typically have degrees in business, economics or engineering and be driven by business metrics, such as economic profit and short-term results, academia will have educational backgrounds in scientific disciplines and be driven by academic recognition, based on publications and conferences, typically on a medium- to long-term horizon.

Yet, by joining the complementary strengths of business and academia, valuable contributions can be made to the economy and society. Business people can add value by identifying market opportunities for innovative products and services, while academics can provide adequate scientific and technical solutions to enable such innovations – the combination of both makes it possible to unleash the full potential of the national innovation system. The cross-country variation in the adoption of technologies accounts for at least 25% of per capita income differences (Comin and Hobijn, 2010[93]). Furthermore, changes in the pattern of technology diffusion account for 80% of the income divergence between rich and poor countries since 1820 (Comin and Ferrer, 2013[94]).

Etzkowitz (2002) identifies various models of government intervention in favour of academia-business linkages, including the statist model, whereby the state takes a leading role in establishing partnerships with a relatively weak academic and private sector, such as was in place in the Soviet Union, France and Latin American countries during the second half of the 20th century. This contrasts with the “laissez-faire” model applied in the United States throughout most of the 20th century, where the role of government is limited to correcting market failures, leaving an open ground to academia in charge of knowledge production and business responsible for knowledge absorption. However, the relationship between the actors and the policy-making process is not always static, as described above. In both models, there is a pull to increase the independence of university and industry from the government and increase interdependence among the three partners. To better describe these dynamic partnerships, Etzkowitz proposes an alternative model: the Triple Helix interactive model, where academia, business and government are interdependent and relatively equally important stakeholders (Etzkowitz, 2002[95]).

Nowadays, policy makers reason in terms of knowledge co-creation, as joint production of innovation by industry, research, and potentially also civil society, which facilitates the transfer of tacit knowledge between participants. They exist in different forms, including projects, joint laboratories or industry-led ecosystems, and may use digital technologies that enable collaboration at a distance. They may include hackathons to generate ideas, expert networks and ad hoc teams (Kreiling and Paunov, 2021[96]).

Overall, fostering university-industry collaboration is a challenging policy issue, as the development of such collaboration relies on a very complex set of good practices (Awasthy et al., 2020[97]).

4.7.2. An historical overview of knowledge flows in Korea

A legal framework for university-industry co-operation has existed in Korea since the 1963 University-Industry Co-operation Act. However, until around 2000, there were limited knowledge flows from universities and GRIs to the business sector in Korea. Universities were mainly focusing on teaching, with sparse resources for research. GRIs have been rigidly managed, and their interaction with industry is limited.

Following the initial policies aimed at developing indigenous S&T capacity in GRIs and universities (described in the previous sections), there was a series of restructuring during the liberalisation period of the 1980s, including the merger and de-merger of KIST and KAIST, and the establishment of dominant governmental agencies between 1993 and 1997. The Brain Korea Project, which started in 1999 to increase the research capacity of universities through large central government subsidies, became a potential factor that undermined the culture of co-operation (Park and Leydesdorff, 2010[98]).

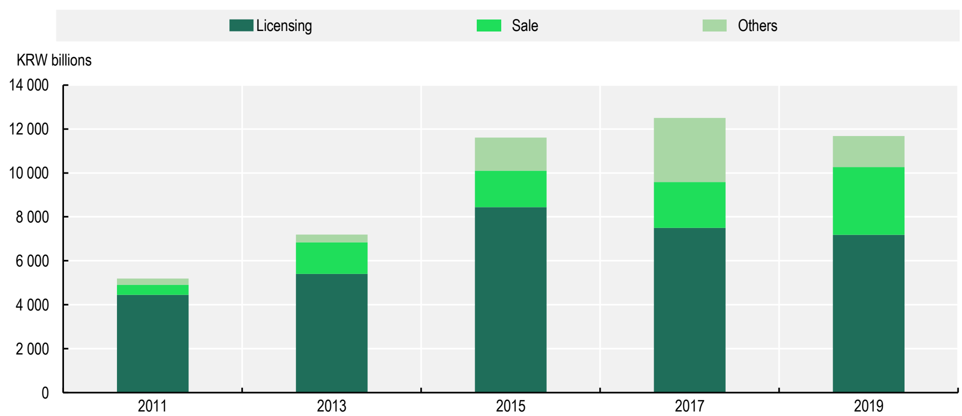
While the relative weight of R&D spending by the higher education sector has declined due to the steep increase of R&D spending by companies, some universities have become research universities with greatly increased funding for conducting cutting-edge research (Shin and Lee, 2015[67]).

Knowledge flows, for instance, technology transfer, from higher education and GRIs, have greatly increased since the turn of the millennium, the real impetus being given by the 2003 revision of the University-Industry Co-operation Act, whereby universities were allowed to create for-profit companies based on academics' inventions. In parallel, as mentioned above, a Korean equivalent to the US Bayh-Dole Act, the Promotion of Technology Transfer Act, was enacted in 2000 (Kwon, 2015[68]). Those initiatives led PRIs and most public universities to create technology licensing offices (TLOs) and industry-university co-operation foundations (IUCFs). As of 2019, 354 among 416 universities in Korea (including technical colleges and vocational schools) had IUCFs (Ministry of Education and NRF, 2021[44]). Although TLOs and IUCFs are formally separate organisations, they work closely together and are often headed by the same person. Organised under these organisations, IP rights related to research outcomes of university staff now belong to universities, not individual faculty (Eom and Lee, 2010[99]).

In terms of budget, the share of ministries' programmes and projects on commercialisation jumped from 0.7% of the total government R&D budget in 2007 to 7.1% in 2020 (STEPI, 2021[62]). This reflects the reorientation of governmental support for knowledge diffusion where multiple government bodies, notably MSIT, MOTIE and the Ministry of Education (MOE), began to form a mutual understanding of the need for integrated support rather than dividing the labour. The targets for support varied across the stages of the innovation cycle. MOE expanded programmes around existing research and business development (R&BD) foundations within universities, MSIT around the science and technology parks (STPs) and MOTIE through its agency, KIAT. Regarding legislative initiatives, the Technology Transfer and Commercialisation Promotion Plan, which is an implementation plan based on the provision of the Technology Transfer Promotion Law, is renewed every three years. The recent 6th and 7th Plans covering the period of 2017-22 increasingly focused on forming the ecosystem for open innovation and bringing in market perspectives to divert the excessive focus on technology centrism. In addition, major national R&D projects were dedicated to university-industry co-operation, including the second phase of Brain Korea, New University for regional innovation and other funds, as mentioned above.

GRIs have been reorganised and subjected to stronger performance pressure by transitioning major parts of their financing from block funding towards competitive bidding for research grants. The patenting rate of GRIs is high in international comparison, according to a 2020 report by the Korean Intellectual Property Office, which compares the number of patents per unit of financing and finds such an efficiency to be several times higher in Korea than in leading US or Japanese universities and institutions (KIPO, 2020[100]). This indicates a high potential for knowledge transfer from GRIs to industry, even though the commercialisation is less successful. While IP revenues vary across GRIs, most only have a small income from intellectual property transfer. Technology transfer from GRIs and universities to companies has markedly increased in Korea. The number of technology transfer cases from GRIs and universities to industry more than doubled between 2011 and 2019, from 5 193 to 11 676, and they were almost evenly split in 2019 between GRIs with 6 077 cases and universities with 5 599 cases (MOTIE, KIIP and KIAT, 2021[103]). A majority of transfer cases are based on licensing. However, the relative importance of technology sales and other methods, which include free licensing or transfer, coaching and equipment transfer, is increasing (Figure 4.24). The technology transfer income of GRIs and universities has also increased, from KRW 125.8 billion in 2011 to KRW 227.3 billion in 2019. GRI transfer income is higher than that of universities (Figure 4.25).

Figure 4.24. Number of technology transfer cases from Korean government research institutes and universities to industry, 2011-19

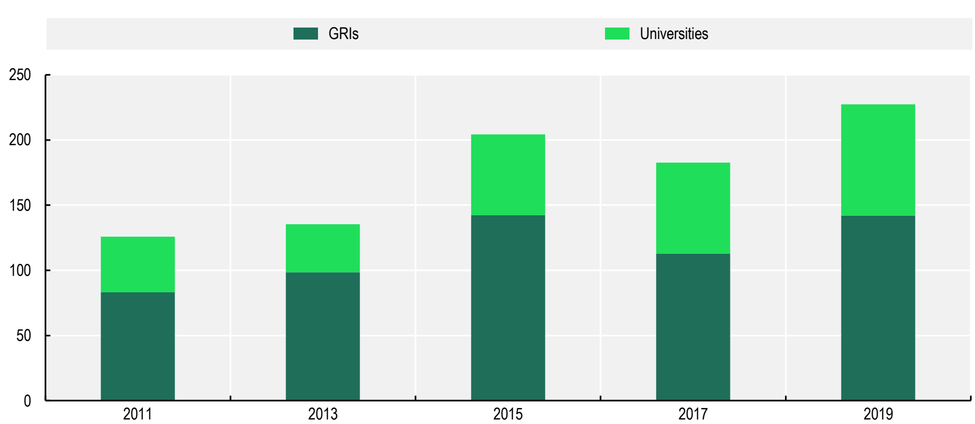


Source: MOTIE, KIIP and KIAT (2021[103]), *2020 Report on the Technology Transfer and Commercialization Survey, based on the 2019 Outcomes of Public Sector Research Institutes*, https://www.ntb.kr/marketTrend/selectStatsReferView.do?bbs_seq=24#file.

Finally, Korean industry has multiplied its R&D spending. Many companies have reached the technological frontier and, therefore, need to acquire more scientific knowledge to innovate successfully (Lee, 2011[101]). Technology transfer from GRIs to the private sector is promoted as well. GRIs run their own specific knowledge transfer programmes to external organisations, with a particular emphasis on knowledge transfer to SMEs (National Research Council of Science & Technology, 2022[102]).

Figure 4.25. Technology transfer income of Korean government research institutes and universities, 2011-19

In KRW billions



Source: MOTIE, KIIP and KIAT (2021[103]), *2020 Report on the Technology Transfer and Commercialization Survey, based on the 2019 Outcomes of Public Sector Research Institutes*, https://www.ntb.kr/marketTrend/selectStatsReferView.do?bbs_seq=24#file.

4.7.3. The current state of academia-industry linkages in Korea and a way forward

As is evident from the above, much effort has gone into enhancing the academia-industry linkage, particularly since the turn of the millennium, which has fuelled some of Korea's technological development. This section takes stock of the current state and tries to draw some learnings for the future.

Three Korean universities – SNU, KAIST and POSTECH – rank 1, 2 and 3, respectively, in Reuters' 2019 ranking of Asia Pacific's most innovative universities, which is based on patent statistics and counts of research citations in patents,[21] followed by prestigious Tsinghua and Tokyo universities at ranks 4 and 5. Overall, 19 Korean universities are among the top 75 in this ranking, on par with Japan and second only to China, with 25 institutions. SNU posted 907 patent families between 2012 and 2017, reaching a commercial impact score of 38.7, while KAIST filed 695 patents and reached an exceptional commercial impact score of 57.8. POSTECH filed 349 patents with a commercial impact score of 48.8. Nevertheless, the ranking would be reversed if measured per staff member since SNU is much larger, and thus patenting per staff member is much higher in KAIST and POSTECH (Table 4.13).

Table 4.13. Reuters' 2019 ranking of Asia Pacific's most innovative universities

Top 20 universities

University	Country	Staff	Total patent families filed, 2012-17	Success rate	Commercial impact score
SNU	Korea	2 099	907	78.2%	38.7
KAIST	Korea	895	695	79.4%	57.8
POSTECH	Korea	446	349	79.7%	48.8
Tsinghua University	China	3 416	834	62.7%	34.8
University of Tokyo	Japan	3 801	971	52.6%	32.5
Osaka University	Japan	3 225	618	52.1%	33.6
Kyoto University	Japan	2 578	703	48.5%	29.0
National University of Singapore	Singapore	1 803	439	33.5%	41.3
Sungkyunkwan University	Korea	2 904	252	77.0%	30.9
Peking University	China	4 735	469	54.8%	27.5
Hanyang University	Korea	1 428	506	77.9%	33.2
Kyushu University	Japan	2 473	551	52.8%	25.4
Tohoku University	Japan	3 195	649	59.8%	25.8
Yonsei University	Korea	1 951	561	78.6%	24.4
Nanyang Technological University	Singapore	1 561	472	40.0%	43.5
Korea University	Korea	1 474	502	85.7%	24.2
Zheijang Universiy	China	3 562	243	62.6%	27.4
Tokyo Institute of Technology	Japan	1 311	341	54.5%	23.8
Kyung Hee University	Korea	1 365	264	79.9%	28.6
Fudan University	China	2 721	130	56.9%	29.6

Note: Total patent families measures the number of basic patents filed by the institution between 2012 and 2017. Success rate is the ratio of patents filed by the institution between 2012 and 2017 that were subsequently granted by patent offices. Commercial impact score is an indicator of how often basic research originating at an institution has influenced commercial R&D activity, as measured by academic papers cited in patent filings. Higher scores are better.
Source: Ewalt (2019[104]), *Asia Pacific's Most Innovative Universities 2019*, https://graphics.reuters.com/ASIA-UNIVERSITY-INNOVATION/0100B02G03Z/index.html#:~:text=KAIST%20falls%20from%20first%20place,of%20projecting%20dynamic%203D%20images.

Among SNU's inventions, the new "lipid nano tablet", resembling the membranes of living cells, could represent a breakthrough leading to the development of ultrasmall biologically based computers, whereby computing is performed by nanoparticles bonded to pieces of DNA, while KAIST has invented ultrathin holographic displays capable of projecting dynamic 3D images. In addition, POSTECH invented artificial corneas that are 3D-printed out of tissue-derived "bio-inks", making them transparent, robust and better to transplant in human eyes. Sungkyunkwan University, Hanyang University, Yonsei, Korea University and Kyung Hee University are also within the top 20 in this ranking (Ewalt, 2019[104]). All these examples are a good indication of the innovation that fostered industry-academic collaboration can induce. Promoting partnerships and joint research can help real-world applications of research findings.

Nevertheless, these metrics are most relevant for the linear model of technology transfer, whereby knowledge is generated at universities and then "pushed" into commercialisation. This has made Korea successful in the catch-up mode, but there is room for improvement at the technology frontier. Hameed, von Staden and Kwon (2018) suggest that Korea should now adopt a different model. For this to happen, the shared mental model in university-industry interactions needs to move towards demand-oriented technology transfer practices rather than supply push. At the same time, policy orientation should evolve from institutional and top-down mode towards more participatory and bottom-up (Hameed, Staden and Kwon, 2018[105]). In this respect, Korea may want to follow some of the good practices of co-creation between academia and industry, including projects, joint laboratories, industry-led ecosystems, hackathons to generate ideas, expert networks and ad hoc teams (Kreiling and Paunov, 2021[96]).

Technology from GRIs and universities is predominantly transferred to SMEs, the technology recipients in 90.8% of all transfer agreement cases in 2019. In contrast, only 2.0% of all technologies were transferred to large firms and 2.4% to mid-sized companies. Most technologies are transferred via patents, which 69.3% of all technology transfer cases from GRIs and universities have been based on in 2019. Technology transfer from GRIs and universities is occurring almost exclusively in a domestic context. Only 0.3% of all transfers in 2019 were made to overseas organisations (MOTIE, KIIP and KIAT, 2021[103]).

Universities and large companies often find it difficult to establish common ground in Korea, not least due to their strong separation of tasks and limited interaction in the past. Recently, the Ministry of SMEs and Startups has dedicated a budget of about USD 46 million for the issuance of innovation vouchers for SMEs with a high growth potential of up to USD 37 000, which can be used relatively flexibly for seeking technology consultations from university researchers (Korean Ministry for SMEs and Startups, 2022[106]). Chapter 3 elaborates on government support for business innovation in-depth. Beyond introducing such financial instruments with lower entrance barriers than competitive grants for university-industry research collaborations (UIRCs), another potentially effective way to strengthen knowledge transfer from GRIs and universities to companies is programmes that focus on networking. Person-to-person networks are highly important for effective inter-organisational collaboration in Korea's relationship-oriented culture (Hemmert and Kim, 2020[107]).

Based on desk reviews and interviews, there are some indications that the investment environment and culture around entrepreneurship at universities is changing, incentivising more professors to establish their own start-ups rather than licensing technology to companies, which had previously been the preferred approach. More specifically, some of the conditions around personal risk are being eased so that professors do not need to invest their own assets into starting a business, as, increasingly, universities assist in providing equity that they can use to start a business without being liable with their own funds. KAIST, for instance, while not providing its own seed funding, engages in efforts to link venture capitalists among its alumni network (as well as external ones) with start-ups at the university. From spring 2021 onwards, KAIST has additionally started its own holding company through which it takes shares in the newly founded companies and brokers' relationships with other investors. Finally, professors across Korean universities can start their businesses parallel to their academic careers, for instance, by reducing teaching hours instead.

According to interviews held by the project team, student entrepreneurship has largely increased due to start-up programmes, such as the Tech Incubator Program for Start-up (TIPS) (see Box 4.4). In the case of KAIST, a specific entrepreneurship education curriculum encourages students to engage in start-up creation and has been quite successful. For instance, as part of the "K-School" dual major programme, students enrol in a business major besides their tech-oriented field. Furthermore, there are initiatives in place that also intend to spur start-up activities among university professors, which are traditionally low at around 7-8% of professors embarking on starting their own businesses. For example, professors at some Korean universities can start their businesses parallel to their academic careers, i.e. with the option to reduce teaching hours instead. Still, at the top universities, in particular, professors tend not to take the risk of starting a business. In smaller universities, there is often higher pressure for professors to find jobs for their students; in such cases, co-operation with the private sector is particularly important.

Box 4.4. Tech Incubator Program for Start-up (TIPS)

The TIPS policy programme was introduced by the Korean government under President Park Geun-Hye in 2013 and was largely inspired by the Israeli Technology Incubator programme. Due to its significant success, the succeeding Moon Jae-in administration maintained and expanded the TIPS programme.

The procedure involves private companies that initially angel invest around USD 0.1-02. million in the most promising start-ups, which are then recommended to and complemented by the government with R&D, commercialisation and marketing funding. The objective is to incubate these companies with no more than USD 0.5 million within two to three years before they become globally operating companies and support them with mentoring, education, and funding. In July 2018, the post-TIPS policy was established, which entails further follow-up support amounting to an additional (maximum) USD 0.5 million. Between 2013 and 2019, around USD 450 million was allocated to TIPS by the government, of which USD 308 million was for R&D, USD 54 million for commercialisation, USD 29 million for marketing and USD 21 million for post-TIPS support.

The main success factors of TIPS are the selection by highly experienced private sector companies, business angels and venture capitalists who then support the early-stage companies with valuable mentoring and educational support. Moreover, the programme has managed to involve many professionals and highly educated students, with about 60% of founding team members having a postgraduate degree and thus being a crucial driver of entrepreneurship at universities. By the end of 2018, job creation through TIPS was, on average, 5.5 employees per firm or about 3 690 staff in total. By 2022, more than 1 300 start-ups had been supported, 90% of which had registered IP. The overall government support amounts to KRW 700 billion, while KRW 4.7 trillion comes from the private sector. Only around 20 of the 1 300 firms failed and had to exit the market, a success rate of 98%. This contrasts with the low success rate achieved before the TIPS programme when the government directly supported start-ups. The TIPS programme has been so effective and successful because it circumvents the so-called "death valley" in Korea, the fact that venture capitalists are often reluctant to finance in the initial phases to start production, and there are few super angel investors. The objective is to increase the annual number of supported early-stage firms by 500 annually to 3 500 by 2030.

Source: Han (2019[108]), "Promotion of Technology-based Start-ups: TIPS Policy of Korea"; TIPS Korea (2018[109]), *Meet Our Extra-ordinary Start-ups*, http://www.jointips.or.kr/bbs/board.php?bo_table=eng_startup; OECD stakeholder interviews, 2021.

Kim and Cho (2022) provide a literature review of commercialisation success factors for technology transfer and commercialisation, including R&D capability, management ability and technology diffusion capability for the technology provider, as well as technology absorption capacity, commercialisation willingness and capability on the recipient side and technology characteristics, IP rights and environmental conditions, such as government support and co-operation partnerships. They study commercialisation practices in the case of ETRI and introduce the concept of technology commercialisation proactiveness (TCP) for both SMEs and GRIs. TCP for SMEs is measured based on technology transfer expenditure and frequency, while the GRI TCP is measured according to the degree and type of GRI researchers' support. Both TCPs are found to have a positive effect on technology commercialisation success (Kim and Cho, 2022[110]).

Min, Vonortas and Kim (2019) studied the commercialisation of technologies from universities and GRIs in 669 cases. They found that the post-transfer partnership of the company with universities and GRIs positively affects the successful commercialisation of transferred technologies. In contrast, the recipient company's absorptive capacity does not significantly impact the successful commercialisation of technologies sourced from universities and GRIs. They also found that market competition intensity negatively affects the success of commercialisation (Min, Vonortas and Kim, 2019[111]).

In addition to building infrastructure for knowledge transfer from GRIs and universities, the Korean government has also introduced support policies for the technology collaboration of GRIs and universities with companies, focusing on knowledge transfer to SMEs. An online platform has been created that allows SMEs to search for specific technologies developed by universities and GRIs (Korea Technology Finance Corporation, 2022[112]). Another recently promoted knowledge transfer channel is contract research given by SMEs to universities and GRIs (Ministry of SMEs and Startups, 2019[113]). Recent statistics on collaborative research projects by GRIs show that approximately two-thirds of all projects involving the private sector are contract research projects (National Research Council of Science & Technology, 2022[102]). The number of collaborative projects of GRIs with universities is approximately half that of projects with the private sector, indicating that there is also some collaborative research activity between GRIs and universities.

In the case of UIRCs, collaboration partners can apply for government subsidies offered by various programmes by different government agencies, which typically cover approximately 60-70% of all project expenses. A major UIRC support platform in recent years has been the Leaders in Industry-University Co-operation (LINC) programme, which had a total budget of KRW 390 billion in 2021 (LINC, 2021[114]). Overall, there appear to be relatively few UIRCs that do not rely on government subsidies. Most UIRCs are short-term and small-scale; however, some are developed to an advanced level and big scale in which technology transfer could be conducted (Hemmert, 2017[115]). The project duration is rarely longer than three years and often only one year or shorter. Projects tend to have modest budgets of KRW 100 million or less. University partners are mostly not leading research universities but smaller universities that are often located outside the capital agglomeration of Seoul.

A reason for faculty's low UIRC participation rate in research universities is faculty evaluation policies, which emphasise publication in leading academic journals over industry collaboration projects (Park and Leydesdorff, 2010[98]). Faculty at leading research universities with the largest R&D budgets are incentivised to focus purely on academic work and are often inactive in UIRCs. Another partial obstacle to collaboration and knowledge transfer between universities and industry is a limitation on faculty at national universities from receiving income from work in the private sector. [22]

On the industry side, large Korean companies tend to work with foreign universities when developing fundamental technologies, as they perceive that foreign universities are most advanced in basic research. Conversely, UIRCs with universities within Korea tend to focus on developing applied technologies. UIRCs have become more frequent and vibrant at leading research universities. As some researchers at these universities are now recognised as internationally leading in their scientific fields, more and more companies are eager to work with them, as they assume that collaborating with them may enhance their technological competitiveness.

While UIRCs overall have become more frequent in Korea than in the past, the quality of knowledge being created and transferred often appears modest. This is because most UIRCs are conducted between relatively small non-research universities and SMEs, which are often located in geographic proximity to their university partners. As UIRCs also tend to be small-scale and short-term, the content of these collaborations tends to focus on incremental new product or process innovations.

Policies towards strengthening linkages between academia and industry in Korea have focused on financial instruments, such as supporting the establishment of TLOs and IUCFs and grants for UIRCs. Regulatory instruments have also been used, such as assigning IP to universities instead of individual researchers. In contrast, there is little emphasis on soft instruments such as awareness raising, networking and training programmes, which constitute an important part of the policy mix to support knowledge transfer from academia to industry (Guimón and Paunov, 2019[116]).

Korean policy support for university-industry collaboration is seen as weak in an international comparison of environmental, technical and managerial dimensions. In contrast to Israel and Singapore, which are seen as having highly developed policies across the board, Korea's policies are "developing" at best. Korea's policies are particularly underdeveloped in the area of broader research policies that establish a favourable environment for collaboration, information sources for collaborations, intellectual policies and practices conducive to fostering and sustaining collaboration, and the extent to which collaboration is emphasised in institutional leadership priorities and incentives (Dollinger, Lodge and Coates, 2018[117]). Box 4.5 sets out government-led initiatives to support university-industry collaboration.

One policy instrument that appears to have been effective in stimulating knowledge transfer from universities to industry is the provision of financial support for company facilities, such as innovation parks, on university campuses. Companies are incentivised to move into these facilities, as their usage cost is lower than for normal office premises due to government subsidies. Once companies are located on campus, collaboration with university researchers becomes more vibrant due to high geographic proximity.

Box 4.5. Government-led action in favour of university-industry collaboration in Innopolis and Innotowns

Korea has 5 Innopolis in Daedeok, Gwangju, Daegu, Busan and Jeonbuk and 12 Innotowns that aim to promote technology commercialisation in PRIs based on regional needs, as well as 19 science and technoparks focused on fostering local industries and the creative economy innovation centres (CCEI) on start-ups. This is concurrent with the development in many OECD countries where they systematically create comprehensive infrastructure providing office and laboratory space to foster the creation of "deep tech" start-ups with adequate services, such as dust-free labs, supercomputing platforms and/or services such as strategy, marketing, IP, legal, human resources and other consulting (e.g. the EPFL1 Innovation Park in Switzerland) as well as competence or excellence centres for public-private co-operation on projects and programmes (e.g. the Austrian COMET programme).

In Korea, the original objective in the 1970s was to establish "science towns", such as the Deadok Science Town, created as clusters combining GRIs and universities, adding private R&D and venture firms to the cluster in the 1990s, technology commercialisation and a hub-and-spoke system linking its unique research capacity with advanced industries across the country as of 2005.

Daedok is situated one hour from Seoul, Daegu, and Gwangju. Started as a greenfield operation in 1973, it comprises 30 government-funded institutions, 5 universities, over 400 corporate R&D centres and more than 1 200 high-technology SMEs as of 2012. As of 2010, Daedok Innopolis employed 11% of all PhDs in Korea (Oh and Yeom, 2012[118]). This is a typical example of the "statist triple helix model", as defined by Etzkowitz. While the government has successfully provided human capital, infrastructure, technology and competitive research institutes, the more tacit elements, such as inter-firm interaction, shared know-how and spillover of expertise, have been less successful. The development of linkages has been less successful than, for example, in the San Diego biotechnology cluster, due to insufficient networking activities (Kim and An, 2012[119]).

The original Innopolis were considered too big (more than 40 organisations per cluster) to generate significant synergies, and this is why much smaller Innotowns were created in 2019, designed to be "small but robust R&D zones", run by the regional government and focusing on stakeholders from universities, GRIs and businesses with high innovation potential in a limited zone to prevent excessive geographical spread.

Source: Kim and An (2012[119]), "A comparison of Daedeok Innopolis cluster with the San Diego biotechnology cluster", https://doi.org/10.7165/wtr2012.1.2.118; Oh and Yeom (2012[118]), "Daedeok Innopolis in Korea: From science park to innovation cluster park to innovation cluster", https://doi.org/10.7165/wtr2012.1.2.141.

Overall, much has been achieved in academia-industry collaboration, in particular as a support to the SME sector, giving rise to increasing numbers of patents and technology transfer cases. However, this support remains strongly driven by "supply push" rather than company demand driven. In addition, collaboration occurs primarily with SMEs, while the chaebols' innovation ecosystems are relatively disconnected from academia, even though Samsung collaborates significantly with top academic institutions. Therefore, specific incentives should be envisaged for academics who collaborate with industry, particularly large companies (chaebols). Namely, such collaborations can be especially challenging due to the high standards required by results-oriented conglomerates, which can prove to be more competitive than regular work on project-based research work. Evaluation criteria also need to evolve from purely quantitative ones (counting patents and technology transfer cases) towards more qualitative evaluations looking at breakthrough innovations created for the markets, as well as for addressing societal challenges.

4.8. Synthesis

Table 4.14sets out the main achievements and challenges of the Korean research system, focusing on GRIs and HEIs.

Table 4.14. Korea's main achievements and challenges related to its research system

Achievements	Challenges
Research and innovation performance • Korea has the highest government expenditure on R&D in the OECD. • The share of the business sector's higher education expenditure on R&D is the highest in the OECD. • Korea has a very strong start-up support ecosystem, see, e.g. TIPS programme. • Korea has among the highest shares of graduates in science and technology fields and top-performing students in these fields.	Research and innovation performance • Despite significantly higher expenditure on R&D, research outputs in terms of quantity and quality are just on par with the OECD average. • Revenues from intellectual property are lower than in other OECD innovation leaders and remain stagnant. • Compared to other OECD innovation leaders, academic-industry co-publications are low and declining. • Korea is seeing strong skill discrepancies across age groups, with low ICT skills in the old-age population.

Achievements	Challenges
Government research institutes • Korean GRIs show, in part, successful adaptation in their role and contribution to research and innovation. • Some GRIs lead the innovation frontier and are active in highly innovative technology development and commercialisation.	Government research institutes • The rise in PBS funding may incentivise focusing on short-term priorities set by the government rather than impact. • GRIs are largely reliant on PBS, causing concern about the possibility of providing a long-term research orientation and profiling. • Despite the R&R exercise, it is unclear if R&Rs align with the national strategy or innovation system.
Higher education institutions • Higher education expenditure on R&D has strongly increased. • Korea has seen a strong performance of its IST universities and some flagship universities, including Seoul National University. • The role of HEIs has changed drastically since the 1990s and has pivoted towards assuming a key function in research and the national innovation system.	Higher education institutions • Tuition fee freezes, and sharply declining numbers of students exert pressure on HEIs, notably in rural areas. • Korean universities perform poorly in research quality-focused international university rankings, and there is a strong discrepancy between IST universities, SNU and other universities.
Knowledge flows between academia and industry • Korea has seen strong growth in patenting and technology transfer cases in the past two decades. • Korea sees a high number of industry-academia co-publications, above the OECD average (but declining). • According to Reuters, three Korean universities are seen as the top three innovative universities in the Asia Pacific based on patenting and the citation of basic research in patent applications.	Knowledge flows between academia and industry • Most collaboration occurs between academia and SMEs, driven by strong government subsidies, while collaboration with chaebols is less widespread. • There are insufficient incentives for top academics to engage in academia-industry collaboration. • There is a continued prevalence of supply push rather than demand-driven collaboration.

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Notes

1. GOVERD represents the component of GERD incurred by units belonging to the government sector. It is the measure of expenditures on intramural R&D within the government sector, including all units of central, regional or municipal government, including social security funds, and all non-market non-profit institutions that are controlled by government and that are not part of the higher education sector.

2. This ranges from 0.6-0.7% in emerging countries such as Islamic Republic of Iran and Indonesia, to 6.5% in Germany and 8.3% in Sweden.

3. It should, however, be noted that Sungkyunkwan University is owned by Samsung and therefore does not constitute a representative case for Korean universities.

4. The historic acronym stands for Conseil Européen de Recherche Nucléaire (European Council for Nuclear Research), reflecting the original focus on nuclear physics at its establishment in 1950. However, today the laboratory exclusively performs research in particle physics.

5. As of 1 August 2022, Albania, Armenia, Bosnia and Herzegovina, the Faroe Islands, Georgia, Iceland, Israel, Kosovo, Moldova, Montenegro, North Macedonia, Norway, Serbia, Tunisia, Türkiye and Ukraine have applicable association agreements in place. Discussions at various stages are in progress with Canada, Japan, Korea, Morocco and New Zealand. For more information, see https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/updates-association-third-countries-horizon-europe-2021-12-21_en and https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/europe-world/international-cooperation/korea_en.

6. For more information, see https://www.embl.org/partnerships/remote/australia; there is also a bioinformatics resource hosted at the University of Melbourne.

7. For more information, see https://www.nrf.re.kr/eng/page/31752ceb-b028-4721-a493-1d46d43b2285.

8. This is GT Online; see https://www.gtonline.or.kr/ for more information.

9. 2019 as the reference year; as in 2020, student mobility has subsided drastically due to the COVID-19 pandemic.

10. For more information, see http://nobelprize.org (2022).

11. For more information, see https://www.leidenranking.com/ranking/2021/list.

12. The ICT core test assesses the basic ICT skills needed to take the computer-based assessment, such as the capacity to use a mouse or scroll through a web page. For further information, see http://www.oecd.org/site/piaac/.

13. For more information, see https://www.kmi.re.kr/eng/main/main.do?rbsIdx=1.

14. RTOs are research institutes with a mission to support innovation in industry. They aim to have technological capabilities at least "a step beyond" those of many companies in industry. They generally work using a three-part "innovation model", in which the state provides core funding to allow the RTO to develop or acquire the needed technological capabilities. In a second stage, they tend to co-operate with more advanced users, who pay the project costs involved (but who are often in turn subsidised to do so via government innovation or R&D support programmes). This deepens the RTOs' technological capabilities, helps them understand how to apply them in industry and standardise or systematise them. In a third stage, the RTOs sell technical services such as measurement, testing, consulting, design, or certification, allowing them to support not only the more but also the less advanced companies. Thus, RTOs aim to offer advanced support to advanced users and less advanced support to those with lower levels of technological capability overall. A recent report from OECD on RTOs (including Korean GRIs) shows that these organisations play an increasing and changing role to support policies that tackle societal challenges.

15. Cluster analysis – or hierarchical cluster analysis (HCA) – is a method in data mining and statistics that seeks to build a hierarchy of clusters. Inspired by Shin (2009[30]), an agglomerative hierarchical clustering method called the Ward's method was applied. Ward's method performs clustering to minimise variance between different clusters, measured by the sum of squares index (E). A similar approach was applied to the top US universities for benchmarking purposes.

16. Such a score thus gives a normalised value of each variable, in that a positive score of *x* signifies a value which is above the average by *x* standard deviations; a score of zero gives a value that is within the average; a negative score of *-y* is a value below the average by *y* standard deviations.

17. Correlation value here refers to the linear correlation coefficient and is obtained by dividing the covariance by the product of the two variables' standard deviations. The range of values for correlation coefficient is -1.0 to 1.0, where -1.0 means perfect negative correlation and 1.0 means perfect positive correlation. Finally, a correlation coefficient of 0 indicates no relationship between the two variables.

18. Excellence indicates the amount of an institution's scientific output that is included in the top 10% of the most cited papers in their respective scientific fields.

19. See also STEPI (2021[62]).

20. These are: Space, Astronomy, Meteorology, Oceanography, Arcticology, Life, Nuclear Energy, Nuclear Fusion, Accelerator, IT, Mechanics, Construction and Transport.

21. The indicator measures the number of citations in patent filings of basic research originating at the university.

22. Educational Officials Act, Article 19-2 (Special Cases concerning Prohibition of Profit-Making Activities and Concurrent Offices). The Article may allow (associate/assistant) professors to serve as an outside director of a private company after obtaining permission from the head of the school, given that this activity does not interfere with the education of his/her students and academic studies.

5 Science, technology and innovation governance for a new era of innovation in Korea

This chapter discusses the historic development and current state of the governance framework of Korea's science, technology and innovation (STI) system. This framework provides strategic orientation to the system, aims to ensure the necessary co-ordination to align actors' plans and resources and lead the implementation of related policies. The chapter also assesses the potential of this governance framework to help Korea face current and future challenges.

STI governance is defined in this chapter as the set of largely publicly defined institutional arrangements that supervise and co-ordinate how the various public and private actors engaged in socio-economic development interact in allocating and managing resources devoted to different policy fields (OECD, 2010[1]). It includes a wide range of components that are deeply embedded in national innovation systems, such as governing bodies and their assigned mandates, incentive structures, administrative rules and guidelines, networks, visions, social norms, values and culture, stakeholder and citizen representation mechanisms, and knowledge management strategies to inform the decision-making process.

The chapter begins with an overview of the historical evolution of STI governance and policy in Korea and the STI governance system currently. The three following sections examine the main current policy actors and review the arrangements to achieve the three key functions of STI governance systems: 1) strategic orientation; 2) programming and budgeting; and 3) policy implementation (Figure 5.1). A dedicated section then deals with the specific systemic strategic and policy initiatives that aim to support the sustainability transition of the Korean economy. The last section synthesises the main achievements and challenges in improving STI system governance in Korea.

Figure 5.1. The three main functions of STI governance in Korea

Source: OECD based on desk research and stakeholder interviews.

Building on a systematic review of the governance mechanisms and institutions in place, the main conclusions of this chapter are as follows.

First, Korea has set up a unique STI governance structure to provide STI strategic directions, align plans and budgets and articulate and monitor interventions across the whole of government. The particularity of this structure lies notably in the powerful mandate of the Presidential Advisory Council on Science and Technology (PACST) and the Ministry of Science and ICT (MSIT) in the cross-governmental co-ordination of the STI system via its Science, Technology and Innovation Office (hereafter, “STI Office”). This “control tower” plays a prominent role in developing the five-year Basic Plan and aligning sectoral ministries’ mid-term and annual plans with it, as well as in the annual budgeting review of research and development (R&D) programmes and their monitoring and evaluation. This governance has been instrumental in ensuring strategic coherence during a period of rapid expansion of the Korean STI system and the shift from a position of fast follower to that of scientific and technological leader in some key high-growth areas.

Second, this STI governance structure is now confronted, however, with two main issues that call for reforms. Firstly, the system's growth calls into question the sustainability of the current centralised co-ordination mechanisms, particularly when more flexible and inclusive governance is required to cope with a turbulent and complex environment. Secondly, like in many other advanced economies, the need to address growing societal challenges requires more issue-based and integrated co-ordination mechanisms that articulate for each challenge the strategic, planning and implementation functions of governance, with direct and continuous interactions between the main decision makers and stakeholders in each challenge area. A key element of agile governance is the integration of strategy throughout the policy cycle to attain specific goals rather than a sequential process characterised by successive functional stages with their own actors and processes.

While there are numerous experimentations with new forms of governance and policy making in many countries, notably around the mission-oriented policy approach, no country has yet fully implemented "third generation" governance.[1] Building on the strengths of its existing governance structure, Korea can become a front-runner in this respect.

5.1. The development of the Korean STI governance system

This section presents the history of the formation of the Korean STI governance system with a view to better understanding the extent to which the current system is influenced by its past. Three main periods are distinguished in the development of Korea's STI governance system. This analysis shows the strong government top-down and centralised governance that has been essential to guiding the contribution of STI to Korea's remarkable growth during the catch-up period (first period). This system has been replaced by comprehensive centralised co-ordination and planning mechanisms in the post-catch-up period (200-22). Korea is now entering a third stage as it faces new economic and societal challenges and must transition to a new sustainable growth model, to be guided by a reformed STI governance system.

5.1.1. The emergence of an autonomous national innovation system (1962-2000)

The national orientations for STI development were set out in various plans, not least the five-year national economic development plans from 1962 until the 1990s[2]. Although the scope of these national plans extended far beyond technological innovation, the importance of their role in acquiring and learning from foreign technologies in targeted industries has been well documented (Pirie, 2008[2]) (Heo et al., 2008[3]). There were other national *dirigiste* planning mechanisms, such as the five-year Technology Promotion Plans. Although they played important roles in gradually building a more self-sufficient STI system that relied upon national knowledge and innovation resources and capabilities, government STI plans and interventions still depended significantly on companies' demand and remained subordinated to economic and industrial development policies. The government research institutes (GRIs) also played a major role in absorbing key foreign technologies and transmitting them to large Korean conglomerates. Private firms also received significant guidance and support from state authorities via subsidised loans, specific licences to enter targeted industries and protective regulations. The benefits of these new technologies and associated learning partially trickled down to other parts of industry through backward linkages and long-term production networks with local small- and medium-sized enterprises (SMEs).

While the first Korean Technology Development Promotion Policy covered the period from 1962 to 1966, the government's role in supporting research and innovation (R&I) activities remained embedded in the national development policy until the 1980s. More autonomous STI policies – i.e. policies that are still connected to other parts of the economy but are driven by a distinct strategy to develop knowledge and innovation with proper decision centres, modes of intervention and resources – started to emerge during this decade. The first national R&D programme, known as the Specific R&D Programme, was initiated by the former authority in charge of science and technology (S&T) (Ministry of Science and Technology) in 1982, based on the Technology Development Promotion Act. This programme was designed to incubate national S&T capacity and promote the development of core technologies. At the same time, following the examples of the United States and Japan, the government introduced a new tool in the form of large pre-competitive consortia that gathered multiple firms and focused on targeted industrial technologies, such as semiconductors and various information technology (IT) technologies. The first was created in 1982 as the Industrial Research Association, modelled after the Japanese Technological Research Associations. Others soon followed, including those in sectoral ministries (Sakakibara and Cho, 2022[4]).[3]

In the second half of the 1990s, an increasing emphasis was put on fundamental research to produce the indigenous R&I knowledge base needed to support cutting-edge technological development (Yim and Kim, 2005[5]). Initiatives to support research commercialisation complemented these investments. Following the need for a nationwide and more co-ordinated R&D programme, the Highly Advanced National (HAN) Project (also known as the G7 Project)[4] was launched in 1992 and ended in 2001. It was the first mid- to long-term national R&D plan. It was deemed instrumental in fostering industries where Korean companies are now global leaders: semiconductors, various IT segments, electronics and automobiles.

During this first period, and particularly until the 1990s, the governance structure of the nascent STI system that underpinned the progressive strengthening of indigenous R&D capabilities was led by the president, the Presidential Secretary's Office and a group of high-level government officials (Seong, 2011[6]). Implementation was also centralised in one organisation that managed all national R&D activities, the Agency of Science and Technology (the precursor of the ministries in charge of research). The first co-ordination council was created in 1973 with the Prime Minister as chair and composed of 14 ministers under the name of the Science and Technology Review Committee. It was not very active in the 1970s and 1980s. However, the need for effective co-ordination increased significantly in the first half of the 1990s as the scale and scope of the system expanded rapidly. It called for a more elaborated governance framework, with a range of specialised competencies and decision-making institutions in different parts of the government. This system expansion was manifest in the rise of private R&D investment[5] and the number of sectoral ministries (agriculture, transport, health, land and construction, etc.) that started to invest significantly in R&D activities. This translated into growing issues of inter-ministerial co-ordination (Oh and Lee, 2013[7]). Issues ranged from overlaps between ministries' programmes and conflicting policy objectives in a context of fierce competition for power and budget to a tendency of ministries to imitate and duplicate each other's programmes rather than initiating ones based on sound strategy and understanding of stakeholders' (notably in industry) needs in their policy area (Hong, 2005[8]).

5.1.2. The maturing of the STI governance system (2001-22)

The growing need for more strategic steering in a changing national and international context and the increase of co-ordination issues led the government to radically change the governance structure at the beginning of the 2000s. The context of significant increases in government R&D expenditures made these reforms at the same time possible and necessary, as an increasing number and broadening range of programmes and projects had to be planned, managed and evaluated. Within five years, the legal framework and organisational structure were set up that, although reformed many times since then, still prevail. These include the creation of the Ministry of Science and Technology in 1998 (based on the previous form of the Ministry of Science and Technology[6]); the establishment of a new, more powerful, co-ordination council (the National Science and Technology Council, NSTC) in 1999; the enactment of the Framework Act on Science and Technology in 2001; the launch of the first five-year S&T Basic Plan in 2002; and the creation of an executive office to take charge of an increasing range of STI governance functions (the Science, Technology and Innovation Office; hereafter "STI Office").

Creating the Framework Act on Science and Technology in 2001 was a key milestone in elaborating the Korean STI governance system. It provided the legal basis for the main organisations and mechanisms to centrally co-ordinate all STI-related policies. Since then, it has been amended several times and implemented through a multiplication of new or reformed funding bodies, enforcement decrees, regulations and programmes. It has also been progressively complemented by various other laws in specific areas (evaluation, management of agencies, etc.).

The launch of the first five-year S&T Basic Plan in 2002 (covering the period 2002-06) marked another important step in developing a system of innovation, with its own strategic orientations developed from the system itself and implemented by competent authorities with their respective modes of interventions. The Basic Plan was the first plan to cover and integrate into one common framework the different facets of the

Korean National Innovation System Model enacted in 2002, from the management of national R&D programmes to the promotion of public awareness of STI, to the development of R&I human resources and skills, to the improvement of technology transfer, and to international research co-operation.

The Framework Act and Basic Plan provided the legal and strategic foundations of the system, but powerful institutions were needed to operate STI governance in practice. This gap was soon filled with the creation of a new and more powerful co-ordination council (the NSTC, as mentioned above), then later the STI Office. Apart from short periods of reduction in size and change of mandate, these two organisations saw their prerogatives significantly augmented in several waves of reforms.[7]

Despite these reforms, co-ordination was still deemed insufficient. Issues of policy co-ordination between different ministries were highlighted in the World Bank review of 2000 (Dahlman and Anderson, 2000[9]) and the OECD 2009 and 2014 Innovation policy reviews of Korea (OECD, 2009[10]; OECD, 2014[11]). To overcome these issues, new laws and mechanisms were set up (i.e. for monitoring sectoral ministries' plans and programmes for forming the R&D budget), and additional power and legitimacy were granted to central executive and deliberative institutions.

There have also been attempts to merge or reorganise ministries and agencies to improve co-ordination and/or streamline structures. For instance, in 2008, the Ministry of Science and Technology (MOST) and the Ministry of Education (MOE) merged to become the Ministry of Education, Science and Technology (MEST). Also significant was the creation in 2008 of the Ministry of Knowledge Economy (MKE), integrating parts of the former Ministry of Commerce, Industry and Energy (MOCIE), the Ministry of Information and Communication (MIC) and MOST. The aim of this "super ministry", active until 2013 when it was disbanded,[8] was to have a more integrated policy structure and to increase co-operation between policy portfolios to strengthen the knowledge and technological base of industries in key industries to develop new sources of growth (not least around semiconductors, IT and biotechnology).

Agencies also underwent several structural changes, such as the creation of Korean Energy Technology Evaluation and Planning (KETEP) from the mergers of four energy R&D organisations. In addition, GRIs have been transferred among various ministries and research councils, though the structure seems to have stabilised somewhat since 2014 (see Chapter 4).

Alongside these structural changes, Korea set up in the 2000s a unique governance system to steer, co-ordinate and implement a fast-growing array of STI government interventions across more than 20 ministries and many agencies. To reconcile this expansion with a tradition of strategic integration inherited from the model in place during the catch-up period, the government granted a powerful mandate to central executive and co-ordination bodies and introduced an increasing number of co-ordination, budgeting and monitoring mechanisms, rules and guidelines throughout the entire government structure.

5.1.3. Towards a new STI governance system: From 2022 onwards

Korea is currently entering a third stage. It is confronted with new challenges, not least the imbalances and polarisation (social, geographic) resulting from its rapid growth period and the threats of societal challenges, such as climate change and ageing. Although significant reforms were implemented during the 2000s as Korea was searching for a "post-catch-up" model, the legacy of the Korean "developmental state" period, during which the government's proactive policies and regulations led the country's growth trajectory, is still present in the centralised STI governance structure and embedded in many actors' mindsets. This could be an asset in finding a new governance model, provided it can be repurposed toward new objectives (a combination of societal and economic objectives), made more integrated (beyond administrative and sectoral silos) and inclusive (to co-create STI agendas with key actors, including citizens when relevant) and focused on experimentation and learning (rather than compliance).

The need for better integration of STI policies, which drove many of the second-stage reforms, is still topical. However, the solutions will have to be different. Although the current model is claimed to allow significant efficiency gains, it needs to evolve to better help Korea tackle the economic and societal challenges it faces today and in the future.

Korea needs to start designing and implementing a “new type of top-down policy” that incentivises more diversified initiatives from all parts of the system to experiment and learn different ways to fulfil inclusively developed and commonly agreed objectives and priorities.

5.2. Overview of the Korean STI governance system

This section presents an overview of Korea’s STI governance system, the result of several reforms over the past two decades. As in many advanced economies, the succession of these reforms shows a process of trial and error in seeking the right governance model. The general trend of these reforms to date has been a reinforcement of the power, legitimacy and resources of central institutions and processes to improve simultaneously: 1) inter-ministerial co-ordination; and 2) better alignment of all ministries’ plans with the central five-year Basic Plan. The government has often justified new changes by arguing that the progress made following previous reforms was insufficient (Hong, 2005[8]; Chon, 2017[12]). The voluminous literature that deals with this period of maturing of the STI governance system focuses on many co-ordination weaknesses: insufficient power of the central councils and the STI Office in relation to the sectoral ministries and/or the financial public authorities; lack of linkages between the council co-ordination and the budgeting functions; insufficient attention of the president on innovation co-ordination issues; and weak secretariat and strategic policy intelligence to feed into council decisions. Efficiency rationales also played a role, such as in 2008, when the new administration strongly emphasised the need for a smaller, more efficient government (Schhüller, Conlé and Shim, 2012[13]).

The section starts with a presentation of the system's organisational structure before providing a review of the powerful central institutions and the multiple governance functions they oversee.

5.2.1. A well-established three-tier STI governance structure

Korea has a well-established three-tier governance structure composed of dedicated institutions with clear legal mandates to perform the essential functions necessary to steer, co-ordinate and implement STI policies. As is typical of advanced economies, the Korean STI system is composed of three main levels of governance:

1. **Strategic orientation/agenda setting**: the level of the executive and legislative branches of government where the strategic framework guiding STI activities is developed.
2. **Co-ordination and programming**: the level of the individual ministries or “administrations”.
3. **Policy implementation**: the level of funding agencies (also known as intermediary or management agencies) which implement policy on behalf of the ministries.

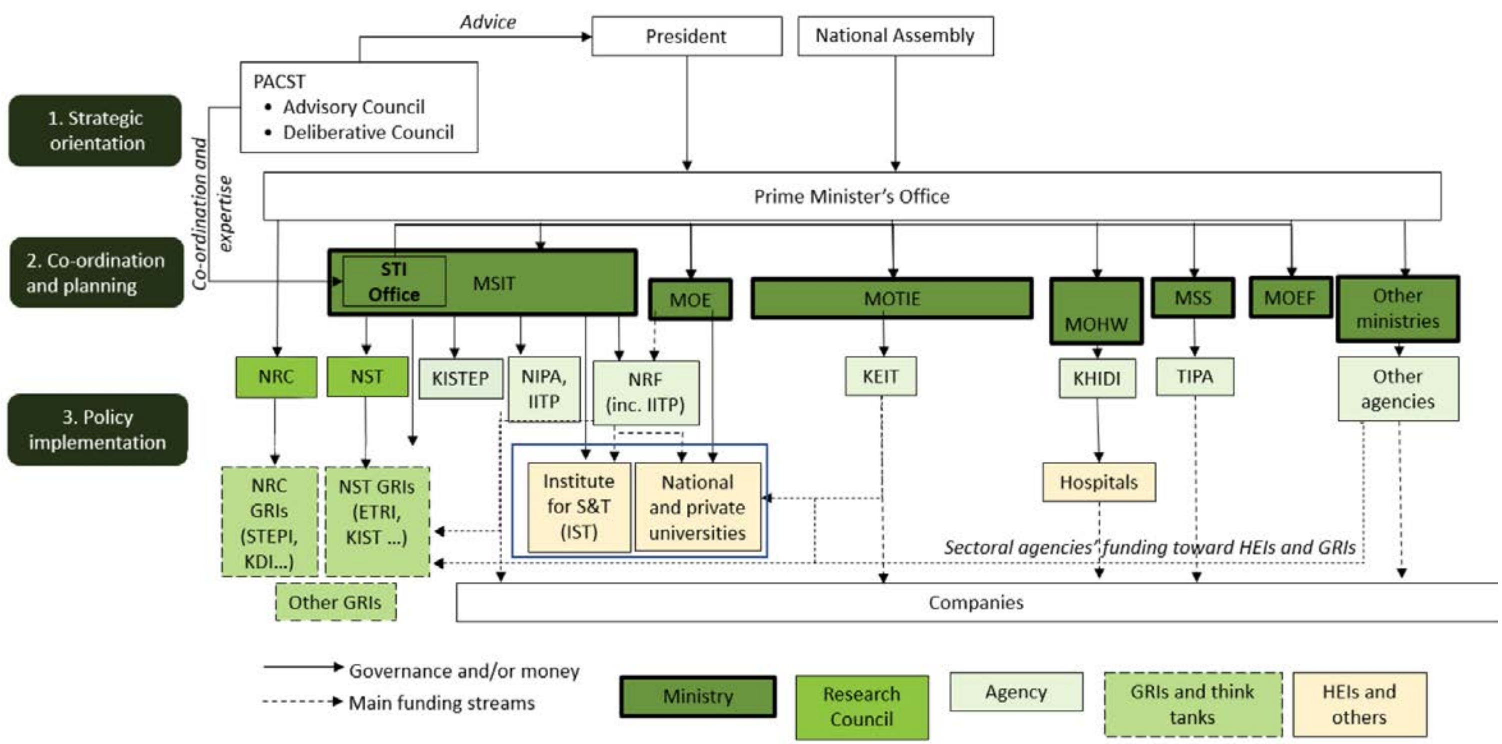
The organisations that perform R&D or innovation (universities, public research institutes, companies and others, such as hospitals, farmers, and so on) form a fourth level that receives funding and associated strategic orientations and conducts activities to generate impact.

Following this typical structure of STI systems, Figure 5.2 presents the Korean STI governance structure across the six ministries and ten agencies that fund and operate significant amounts of R&D in Korea. A more complete picture would include a far greater number of ministries and agencies that develop policies and manage R&D programmes.

The main institutions that compose the Korean system of innovation have distinct roles at the three different levels of the system:

1. **At Level 1 (strategic orientation/agenda setting)**, the president is a powerful actor elected for a single and non-renewable five-year term. Members of the National Assembly serve for four years. The president appoints the Prime Minister as his/her deputy. The president appoints the other ministers, and the Prime Minister runs the Prime Minister's Office (Chancellery). The PACST advises the president and co-ordinates R&D policy across the ministries (except defence, which is treated separately from the rest of the system) (see below).
2. **At Level 2 (co-ordination and programming)**, many ministries fund some R&D.[9] The MSIT is the lead ministry for R&D in terms of funding volume. Importantly, it also hosts the STI Office that supports MSIT's co-ordination function horizontally across the entire government structure. The STI Office is a powerful unit that performs crucial functions that pertain to the three levels: it leads key processes to set orientations, co-ordinate plans and budgets, and monitor and evaluate policy implementation. The Ministry of Trade, Industry and Energy (MOTIE) is another important ministry that deals notably with industrial policy. Therefore, as in many countries, innovation policy is somewhat shared between the MSIT and MOTIE. A comparison with Germany and Japan shows that Korea's R&D expenditures are more distributed across the government structure, which has important consequences for governance. The combined shares of the authorities in charge of research, higher education and industry represent 59% in Korea, 81% in Japan and 77% in Germany.[10] Almost all ministries experienced increased R&D budgets between 2019 and 2023 (Figure 5.3).[11]
3. **At Level 3 (policy implementation)**, agencies implement the government's STI policy and many programmes, most often under the authority of their respective principal ministries. These are normally funding agencies, but often, due to their proximity to public and private organisations that perform R&I activities and their monitoring and evaluation role, they also provide strategic intelligence to their "principals".

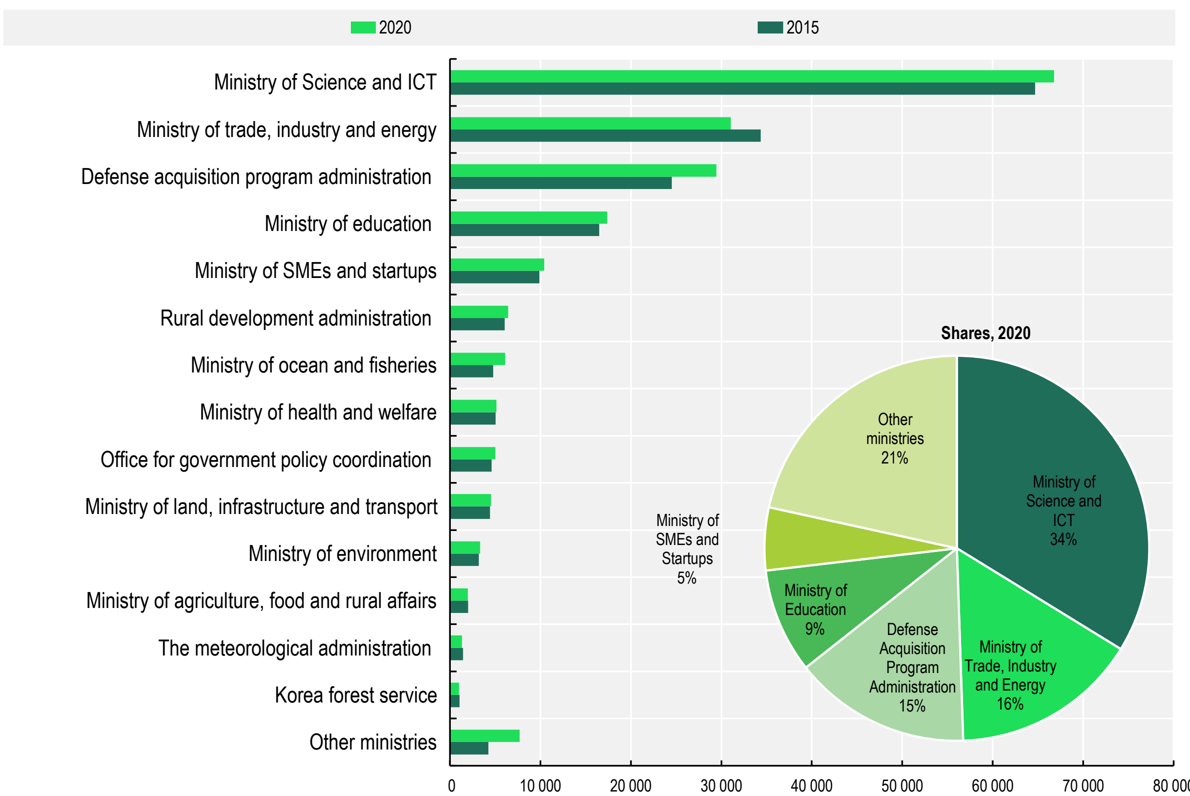
Figure 5.2. Korea's STI governance structure



Note: Full names of institutions here in descending order: Presidential Advisory Council on Science and Technology (PACST), Ministry of Science and ICT (MSIT), Ministry of Education (MOE), Ministry of Trade, Industry and Energy (MOTIE), Ministry of Health and Welfare (MOHW), Ministry of SMEs and Start-ups (MSS), Ministry of Oceans and Fisheries (MOF), National Research Council for Economics, Humanities and Social Sciences (NRC), National Research Council for Science and Technology (NST), National IT Industry and Promotion Agency (NIPA), Institute of Information and Communications Technology Planning and Evaluation (IITP), National Research Foundation (NRF), Korea Evaluation Institute of Industrial Technology (KEIT), Korea Health Industry Development Institute (KHIDI), Korea Technology and Information Promotion Agency for SMEs (TIPA), Korea Institute of S&T Evaluation and Planning (KISTEP), Korea Institute for Industrial Economics and Trade (KIET).
Source: OECD based on desk research and stakeholder interviews.

Figure 5.3. Trends in implementation of national R&D programmes by ministry, 2019 and 2023

In KRW 100 millions (Korean won)



Note: The figure does not entirely reflect the institutional changes during the measured period. For instance, the Administration for SMEs (in Korean, *중소기업청*) was elevated to the Ministry of SMEs and Start-ups (*중소벤처기업부*). The Ministry of Science, ICT and Future Planning (*미래창조과학부*) was renamed to Ministry of Science and ICT (*과학정보통신부*).
Source: Ministry of Science and ICT (2021[14]), *Science and Technology Yearbook 2021 (과학기술연감 2021)*, https://www.msit.go.kr/bbs/view.do?sCode=user&mId=89&mPid=83&pageIndex=&bbsSeqNo=70&nttSeqNo=1887581&searchOpt=ALL&searchTxt=, p. 602; Ministry of Science and ICT (MSIP, 2015[15]), *2015 Report on National R&D Programme Analysis (Statistics)*, https://scienceon.kisti.re.kr/commons/util/originalView.do?cn=TRKO201800037422&dbt=TRKO&rn=, p. 3.

Under these three levels, the governance system steers, incentivises, supports and monitors the activities of R&I-performing organisations, such as state universities, industrially focused universities of technology, and GRIs, as described in previous chapters.

Many legal acts set out the roles and rules guiding these institutions at all levels. Some of the main ones are presented in Box 5.1.

Box 5.1. Legislation underpinning Korea's STI governance system

The foundations of the STI governance system were set in the Framework Act on Science and Technology (hereafter, "Framework Act") in 2001. It has been amended several times since then and still sets the main legal basis for all STI governance processes, from strategic orientation to co-ordination, programming, budgeting, monitoring and evaluation. It positions MSIT as the main actor steering and monitoring these processes. The different generations of amendments record the gradual strengthening of the central STI functions.

Another major reform is the National R&D Innovation Act of 2021 (hereafter, “Innovation Act”), which aims to rein in and homogenise the structures and processes of the “R&D management agencies” and form an “autonomous and responsible” environment for supporting R&D activities. This act sets out general guidelines to govern the way all ministries fund and implement R&D activities in universities, GRIs and private sector actors. Previously, under the Framework Act, each ministry could establish procedures and standards for selecting, funding, managing and evaluating the R&D activities performed by its agencies. Another objective of normalising processes and procedures across the government structure is to ease joint and co-ordinated activities by ministries. Granting more autonomy and stability to researchers was one of the main objectives of the reform. Management organisations, including universities, must also establish a sound research support system in terms of infrastructures and staff working environment. The act notably includes provisions for management agencies to reduce the accountability burden on researchers. Also, funded projects’ annual contract renewal and annual evaluation were replaced with, respectively, multi-year contracts (for the project duration) and a two-stage monitoring process (i.e. mid-term and final) (Ministry of Government Legislation, 2021[16]); MSIT, 2022[17]).

The Industrial Technology Innovation Promotion Act was enacted in 2006 and most recently revised in 2020. It sets all competencies and procedures to promote innovation of industrial technology and develop the necessary infrastructure. Given the importance of industry in Korea, this is an important legal document that covers the whole policy cycle from strategic plans to evaluation.

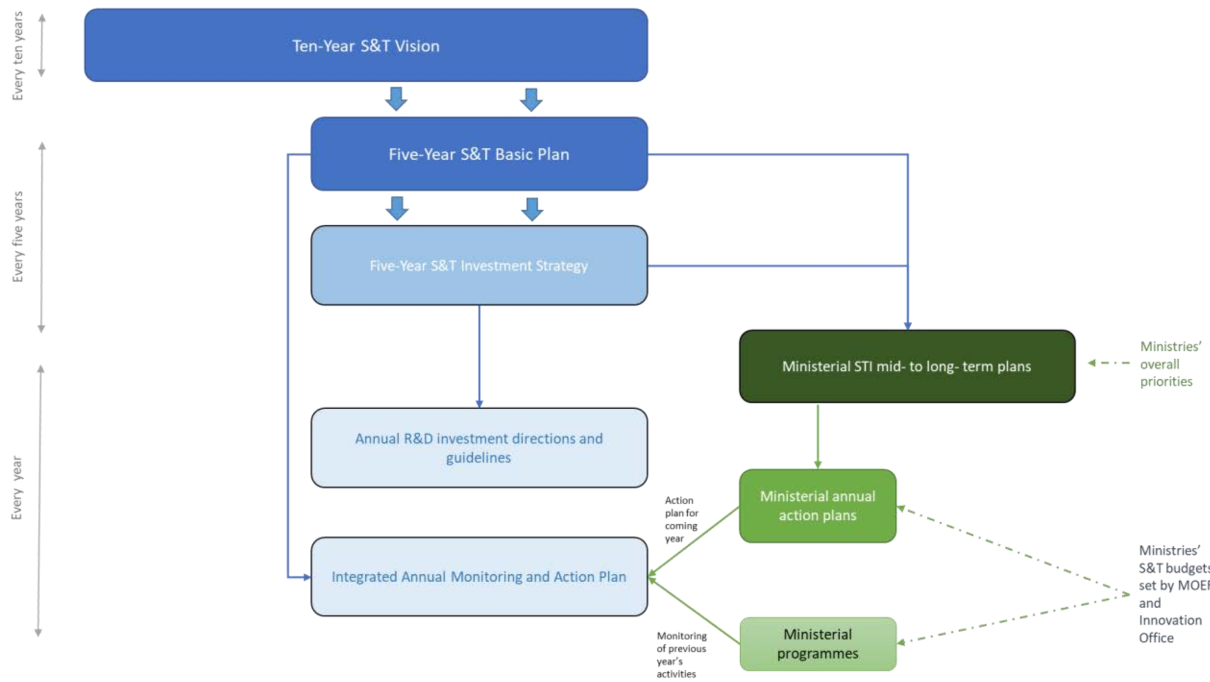
5.2.2. Central processes govern the steering, co-ordination and implementation of STI policies

As in other countries, the sectorisation of STI governance systems in Korea is a strength in that it means many policy actors promote and fund STI. However, sectorisation is a weakness in that it hinders the development of a shared agenda between authorities in different policy areas; complicates the co-ordination of their respective plans to implement this agenda; and makes it difficult to implement joined-up initiatives. While this also holds for small countries – Norway and its strong “sector principle” illustrates this point – it is even more challenging for larger countries like Germany and Korea, with more numerous actors.

Korea has taken up this challenge by setting a unique, comprehensive, and centralised multi-step process to ensure that long and mid-term strategic orientations are concretely considered by all relevant ministries when deciding on their interventions (that mostly take the form of programmes) (Figure 5.4). At the centre of this process is the STI Office, a unit of about 110 employees that plays the role of “STI control tower” with a powerful mandate to review the STI-related plans and “Specific Programmes”[12] of a wide range of ministries, agencies and GRIs who are active in this area. Once reviewed, these plans and specific programmes are to be approved by PACST.

Strategic steering, planning and co-ordination are done centrally with a significant level of detail through a number of processes and mechanisms to ensure policy coherence. Annex 5.A summarises the different governance arrangements involving central interventions from the STI Office and high-level bodies.

Figure 5.4. Korea's STI governance system: From long-term strategic orientations to annual programming and budgeting



Source: OECD based on desk research and stakeholder interviews.

5.2.3. Powerful central STI institutions lie at the core of the STI governance system

Two main organisations jointly lead and/or execute most of the central STI functions, from setting directions to providing guidelines and monitoring and evaluation. These are: 1) PACST, in a deliberative and advisory function; and 2) the STI Office, in a decision-making and executive role. Over the past decades, these organisations have experienced many changes in composition, mandate and institutional status, as well as position in the STI governance system.

High-level advisory and co-ordination bodies

Until 2018, the two highest-level STI bodies for, respectively, strategic advising and co-ordination were PACST and the NSTC. In 2018, these two bodies became two councils under the heading of the PACST General Meeting, following a long history of bodies with advisory and co-ordination functions since the 1970s.

The National Science and Technology Commission until 2018

The NSTC was established in 1999 to strengthen STI co-ordination, which was considered too weak to align the plans of a growing number of ministries increasingly active in R&I to serve their own agendas. An important new feature relative to its predecessors,[13] the NSTC was chaired by the president, who concentrates an important part of administrative power in Korea.

The NSTC has undergone several reforms since its creation, changing its responsibilities, composition and status. The NSTC, for instance, gained and sometimes lost some competencies (e.g. in budget formation through the reforms in 2008 and in *ex ante* and *ex post* evaluations of programmes). It also changed position and chairmanship, and its secretariat evolved. NSTC reforms also reflect the changes in ministries' portfolios and different political choices regarding the desirable level of centralisation.[14]

A key point is that the evolution of NSTC cannot be disconnected from the changes that affected the STI Office during the same periods. The role of the STI Office as the STI co-ordination control tower varied significantly in relation to the priorities of the president and the reluctance of sectoral ministries to accept MSIT's central role (Seong and Song, 2014[18]).

The President's Advisory Council on Science and Technology until 2018

The President's Advisory Council on Science and Technology, currently chaired by the president, was created in 1991 to provide strategic, medium- to long-term advice on S&T. There have been some variations and periods of pause in its operation through amendments to the Presidential Advisory Council on Science and Technology Act. For instance, in 2004, the chair, who previously was a civilian, was made the president to increase its legitimacy and power. Also, from 2008 until 2012, PACST changed its name to the President's Advisory Council on Education, Science and Technology in parallel with the merger of S&T and education ministries and the creation of MEST.

Since its creation, PACST has reported on average 20 times during the presidential cycle of 5 years (PACST, 2022[19]) on national tasks that present a future-oriented vision in the S&T field that deserve comprehensive co-ordination across ministries and relevant stakeholders, and that require a decision from the highest level of the S&T community, namely, the president. Overall, PACST has developed and advised on the role of mid- to long-term S&T policies that reflect the socially and economically important agenda at the time and contribute to the achievement of national goals established by the government.[15]

The newly integrated co-ordination and steering committees under PACST since 2018

Since PACST integrated the National Science and Technology Deliberative Council (NSTDC) in 2018, the advisory and deliberation councils belong to the same overall body. It is chaired by the President of Korea, with a civilian acting as the Vice-Chair.[16] This "merger" aims to simplify the governance system, increase the legitimacy of the PACST (which can now meet in plenary, convening all members) and strengthen the linkages between the STI strategic and co-ordination functions.

PACST is now composed of two bodies (Table 5.1): an advisory body providing high-level strategic recommendations to the President of Korea and a deliberative body with a large mandate covering planning, budget formation and monitoring of R&D programmes. Both are chaired by the President of Korea and the PACST Vice-Chair. PACST also meets in a plenary meeting to deliberate on general matters, including the operation of the PACST and issues for which either the advisory or deliberative body needs the opinions of all PACST members. In 2021, the PACST met in plenary twice; the Advisory Council met eight times; the Deliberative Council five times; and the Expert Committee ten times (PACST, 2022[20]). For instance, PACST held its fifth plenary meeting in October 2021 to discuss revising the act that governs its activities. It was attended by 30 persons, including 6 government officials and 22 civilian members.[17]

Table 5.1. The Presidential Advisory Council on Science and Technology (PACST)'s councils and sub-committees

Councils and sub-committees	Purpose	Composition
PACST plenary meeting	Deliberates on the operational aspects, agendas that require hearings at plenary meetings as deemed necessary by the Deliberative Council or by the Chair	• Chair (President) • Vice-Chair of PACST (civilian) • All civilian and government members of the PACST
Advisory Council	Advises the President on major policy directions, institutional development and other matters concerning national STI development	• Chair (President) • Vice-Chair (civilian) • 12 civilian experts
- S&T Infrastructure Sub-committee - S&T Innovation Sub-committee - S&T Society Sub-committee	Provides specific expertise to the Advisory Council	• Civilian experts
Deliberative Council	Reviews, co-ordinates and approves the major STI policy directions, including mid-term STI strategies and plans and R&D funding	• Chair (President) • Vice-Chair of PACST (civilian) • Five ministers (MOEF, MOE, MSIT, MOTIE, MSS) • Ten civilian experts
- Management Committee	Deliberates on the agendas entrusted for deliberation by PACST and co-ordinates inter-ministerial relations	• Head of the STI Office • Government officials • Civilian chairs of expert committees
- Expert Sub-committee of the Management Committee	Supports the Management Committee by pre-examining the STI and R&D agendas submitted to the Deliberative Council	• Civilian experts
- Special Committee (incl. the CET Committee)	Deliberates on special matters when entrusted by the Deliberative Council	• Head of the STI Office • Government officials • Civilian experts
- Local Science and Technology Promotion Council	Deliberates on the investment in and policy directions for basic research	• Civilian experts
- Basic Science Promotion Council	Establishes the Comprehensive Plan for regional STI development and its implementation plan and co-ordinates the regional STI policies	• Civilian experts

Note: MOEF: Ministry of Economy and Finance; MOE: Ministry of Education; MSIT: Ministry of Science and ICT; MOTIE: Ministry of Trade, Industry and Energy; MSS: Ministry of SMEs and Start-ups.
Source: PACST (n.d.[21]), *Home page*, https://www.pacst.go.kr/jsp/main/main.jsp; PACST (2021[22]), *Council List*, https://www.pacst.go.kr/jsp/council/councilList.jsp?category_cd=2.

Assessing the influence of a strategic and/or co-ordination council is a difficult task. International experience suggests that the main limitations that often affect high-level councils' influence are (Schwaag Serger, Wise and Arnold, 2015[23]):

- Their legitimacy. The chairmanship by a high-level official is generally positively associated with a council's ability to ensure co-ordination and communication between the different sectors (Schwaag Serger, Wise and Arnold, 2015[23]). They can, for instance, be headed by the Prime Minister and include a handful of other ministers central to R&I policy, plus a small number of key stakeholders from academia, industry and society.[18] In Korea, the chairmanship by the President of Korea is meant to ensure a very high level of legitimacy. However, according to the interviews, the president from the former government barely attended the council meetings, and interactions between the council and the president based on some PACST proposals were limited.[19] This was said to have reduced its influence. Also important is the fact that the Advisory Council is composed of private members who theoretically provide direct input to the President without interference from government officials.

- Their scope. The ability of these bodies to influence STI policy as a whole is limited when their scope is not system-wide and/or parallel bodies are acting in their sphere. In Korea, the framework is clear that PACST can deal with all matters related to STI, regardless of ministries' portfolios, and that all ministries are expected by law to implement the decisions of the advisory and deliberative bodies. However, Korea has a multitude of high-level councils, which inevitably results in some overlaps and calls for communication between different councils.
- Their analytical resources. Decisions should be based on thorough analyses, which, if possible, should be carried out not by one ministry but rather by a dedicated secretariat, through interactions with the relevant authorities. PACST is supported by the PACST Support Group (about 25 staff) with significant analytical capabilities. This group is under the advisory body and comprises public officials from relevant S&T ministries and experts from GRIs.[20] However, this appears to be a rather small team for bodies with such a wide mandate. PACST collaborates closely with the STI Office, which oversees the overall STI strategy and policy across the whole government structure.

The Korean model for a high-level STI body is close to that of the Japanese Council for Science, Technology and Innovation (CSTI), which operates with a wide mandate (see Box 5.2). Three important takeaways from the Japanese centralised governance system are:

1. Like the PACST Deliberative Council, CSTI was tasked to review all ministries' STI programmes and budget proposals. However, this was abandoned after a few years as this was considered too resource-intensive and required a range of expertise difficult to handle centrally.
2. CSTI has a mandate and dedicated budget to supervise mission-oriented, high-risk, high-reward programmes that are considered better managed centrally than in any given sectoral ministry.
3. Another committee was created specifically to co-ordinate CSTI with other sectoral committees and develop the annual whole-of-government action plan to implement the S&T Basic Plan.

Box 5.2. The high-level STI committees in Japan

The Council for Science, Technology and Innovation (CSTI)

The CSTI took over from the Council for Science and Technology Policy (CSTP) in 2014. The CSTP was created in 2001 within the Cabinet Office to lead the agenda-setting process and support the inter-ministerial co-ordination of STI policies. One important task of the CSTP was drafting the Basic Plans. The CSTP held meetings headed by the Prime Minister almost once a month. Six out of fifteen members were ministers within the Cabinet, and four other members were executive members, i.e. they were appointed to work full-time for the CSTP. While meetings were short and dedicated to taking official policy decisions, the 4 executive members, a strong secretariat of about 100 staff, a dedicated budget to commission studies and several expert panels to deliberate on specific policy issues gave the CSTP a strong and hands-on role that went beyond simply providing advice to the government. The CSTP saw its power reinforced through various reforms until the CSTI replaced it.

The re-establishment of this high-level body aimed to further reinforce its prerogatives of a central STI "control tower" (while broadly keeping the same composition – the number of executive members has been reduced). After successive reforms of the CSTP mandate and since 2014, the CSTI has been given a wide mandate beyond providing strategic guidance on various key topics, as follows:

- Contribute to the co-ordination and monitoring of the implementation of the Basic Plan by sectoral ministries. CSTI took charge of drafting the new Comprehensive Strategy on S&T and Innovation, an annual action plan to refine the priorities for the coming year in line with the five-year Basic Plans. This role gave this committee more direct power over strategies and policies.

- Contribute to annual budgetary allocations, reviewing budgetary requests from different ministries. CSTI was tasked with collecting information from ministries on STI budgets and advising them and the Ministry of Finance (MOF) on these matters. Prior to this, the budget formation in each policy field was mainly the result of bilateral consultations between the relevant ministries and MOF. For this newly created function, the Science and Technology Budgeting Strategy Committee, located under CSTI, is chaired by the minister in charge of S&T policy and consists of senior officials (Director-General level) from the relevant ministries and agencies. The CSTI executive members attend the committee meetings. The CSTI is tasked with reviewing the budget plans of all relevant ministries before any budget appropriation request, consolidating these budgets to acquire an overall view of the whole-of-government STI budgets and, on this basis, providing these ministries and MOF with advice via a “resource allocation policy”. This process functioned for only three years due to operational difficulties. To consolidate the budget, CSTI members and the secretariat scrutinised the budget plans of various ministries in detail to identify projects with significant STI content. This required technical expertise in both budget mechanics and the substantive content of projects that, even with the support of experts, proved to be beyond the capacity of CSTI and its committee. The rotation of the Cabinet Office staff supporting CSTI compounded this problem. These tasks were also very time-consuming, which hindered the other activities of the CSTI. While the process has not been officially terminated, the Science and Technology Budgeting Strategy Committee has not met in recent years. CSTI currently retains an advisory role in the budget formation process. It dedicates significant effort to clarifying and consolidating the overall STI budget. A new information and accounting system has been developed with a dedicated classification matrix and the use of Natural Language Analysis to scan all ministries’ budgets and identify STI initiatives with less fastidious human intervention.
- Direct involvement in the governance, funding and implementation of key STI programmes. In 2014, the CSTI became responsible for steering and implementing two newly created programmes: the mission-oriented, cross-ministerial Strategic Innovation Promotion (SIP) programme and the high-risk, high-reward, Impulsing PAradigm Change through disruptive Technologies (ImPACT) programme. CSTI provides advice and plays a concrete role in these programmes, in their orientation, selection of powerful programme directors, evaluation, etc. This role in the implementation of programmes that the government deems necessary to manage centrally rather than through sectoral ministries is unique internationally. This creates a direct channel for the high-level strategic orientations contained in the Basic Plan to be implemented across the whole government structure.

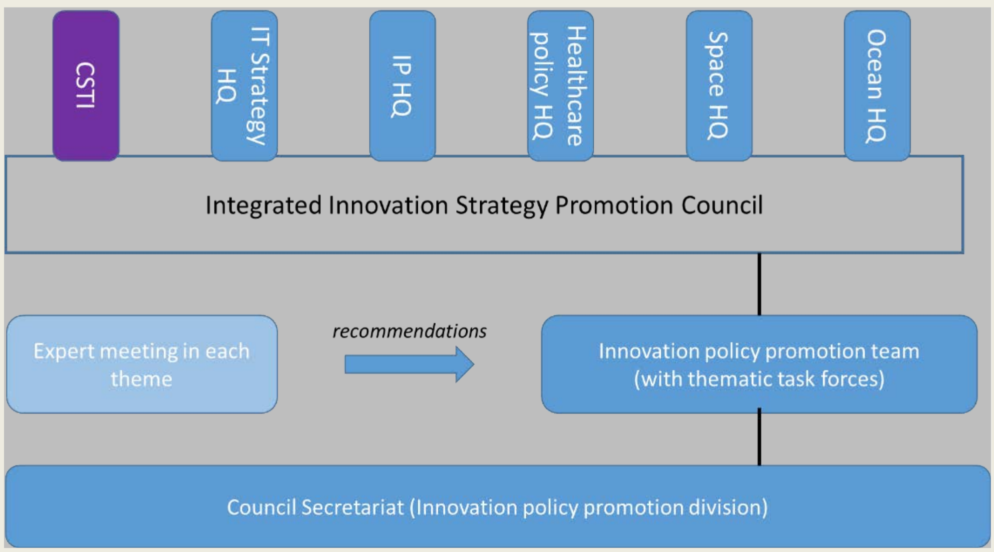
To fulfil this challenging and broad mandate, the CSTI, like its predecessor, is led by the Prime Minister and supported by a robust secretariat under the Cabinet Office. The secretariat includes around 100 staff who generally come from other parts of the government and the private sector for a period of two to three years.

The Integrated Innovation Strategy Promotion Council

In parallel to the strengthening of the CSTP and, later, the CSTI, the government created several headquarters under the Cabinet Office and the Cabinet Secretariat with STI inter-ministerial co-ordination functions in their respective areas (e.g. the IT Strategy Headquarters, the Headquarters for Healthcare Policy, etc.). These bodies take important decisions regarding STI policy interventions in these areas, which contributes to improving inter-ministerial co-ordination, but also runs the risk of overlaps with CSTI. This created a need for co-ordination between CSTI and these systemic sectoral headquarters. In 2018, the annual Comprehensive Innovation Strategies changed name to become the Integrated Innovation Strategies and their scope was widened to include all policy fields beyond those directly in charge of R&I.

In order to co-ordinate the functions of CSTI with those of the area-specific headquarters, the Integrated Innovation Strategy Promotion Council was established in 2018. This council works under the Cabinet Secretariat and is chaired by the Chief Cabinet Secretary. It is composed of several "ministers of state for specific missions" (i.e. ministers positioned in the Cabinet Office who act as heads of headquarters) and CSTI (Figure 5.5). It supports co-ordination between ministries and between "control towers" closely related to innovation and develops and promotes the annual Integrated Strategies. In practice, the CSTI, with its secretariat, leads the drafting of the annual Integrated Strategies.

Figure 5.5. Overview of the headquarters and the Integrated Innovation Strategy Promotion Council



Source: Larrue (2021[24]), "Mission-oriented innovation policy in Japan: Challenges, opportunities and future options", https://doi.org/10.1787/a93ac4d4-en.

The Science, Technology and Innovation Office

The STI Office oversees S&T policies, co-ordinates R&D-specific programmes and evaluates some large-scale and high-priority programmes as defined by law. It was first established in 2004 as a semi-autonomous body following the policy decision to separate the R&D budget authority in the STI area from finance authorities. The Minister of Science and Technology position was promoted to Deputy Prime Minister level to give it more power in relation to other ministries since, with the creation of the STI Office, the ministry received new cross-governmental responsibilities, including defining the R&D budget. The STI Office was reduced to a small bureau in 2008 when the Lee administration (2008-13) took office. In 2011, the government created the NSTC with a structure similar to that of the former STI Office and with a Chair at the Minister level to take charge of the key functions of STI governance – strategic orientation, budgeting and evaluation. During the Park administration (2013-17), the MSIP (the previous name of MSIT) absorbed the NSTC structure and function under a new STI Office (with the Head of the Office at the Assistant Minister level, below Vice Minister). Under the Moon administration, a Head of the STI Office at the Vice Minister level was added on top of the Assistant Minister. The current structure of the STI Office was established at that time.

The main pillars of the STI Office work represented by its three bureaus are: 1) S&T policy planning and co-ordination (Science and Technology Policy Bureau); 2) deliberation and adjustment of the national R&D

budget (R&D Investment Co-ordination Bureau); and 3) performance evaluation of national R&D (Performance Evaluation Policy Bureau) (see Table 5.2). Part of the R&D budgeting authority was delegated to the STI Office by the Ministry of Economy and Finance (MOEF), and since 2016, the STI Office has taken charge of the pre-feasibility test of large programmes, as well as co-ordination of the operational costs of the GRIs. The organisational form and scope of authority are more or less the same as those of the 2004-07 period.

Table 5.2. Internal structure and functions of the Science, Technology and Innovation Office

Bureaus	Divisions	Functions
Science and Technology Policy Bureau	Science and Technology Policy Division Science and Technology Strategy Division Science and Technology Policy Co-ordination Division Growth Engine Planning Division	- Develops S&T policy agenda - Establishes S&T Basic Plans and annual action plans and monitors their implementation - Reviews, analyses and co-ordinates mid- to long-term plans (on R&D) of sectoral ministries - Supports the operations of PACST - Establishes policies bridging R&D budgeting and evaluation - Facilitates inter-ministerial co-ordination - Establishes promotion plan for social problem-solving technology development programmes - Establishes promotion plan for critical and emerging technologies
R&D Investment Co-ordination Bureau	R&D Budget Co-ordination Division R&D Investment Planning Division Public and Energy R&D Budget Co-ordination Division Advanced Manufacturing and ICT R&D Budget Co-ordination Division Biotechnology R&D Budget Co-ordination Division	- Establishes annual investment direction and guidelines - Establishes mid- to long-term investment plans - Oversees matters concerning: ○ Allocation and co-ordination of national R&D programmes and budget of GRIs ○ Establishment and co-ordination of investment strategies for national R&D programmes among R&D actors (industry, academia, GRIs) ○ Improvement of investment efficiency in national R&D programmes, such as co-ordination of overlapping programmes and structuring and restructuring by industry fields - Oversees the establishment of strategies, budget allocation and co-ordination and/or investment directions for specific disciplines/industry fields/technology areas (e.g. space, energy, and environment, ICT and convergence technologies)
Performance Evaluation Policy Bureau	Performance Evaluation Policy Division R&D Assessment and Evaluation Division Research System Division R&D Ethics and Researchers' Rights Protection Division S&T Information and Analysis Division R&D Feasibility Study Team	- Establishes and implements plans and actions related to: ○ Performance evaluation of national R&D programmes ○ Performance management and diffusion of outputs of national R&D programmes ○ Performance evaluation of R&D projects - Provides institutional support for the creation of knowledge ecosystems - Performs (*ex post*) meta-evaluation of national R&D programmes and special programmes - Performs meta-evaluation of GRIs and National Research Council for Science and Technology (NST) - Performs pre-feasibility tests - Oversees matters concerning: ○ Foresight exercises and strategic policy intelligence ○ Improvements in administrative processes in national R&D management (including agencies, regulations, etc.) following the adoption of the Innovation Act

Note: The list of functions is not exhaustive.

Source: Adapted from MSIT (2022) and Ministry of Government Legislation (2022[25]), *Enforcement Decree on Ministry of Science and ICT and the affiliated organisations*.

As shown in Table 5.A.1 (Annex 5.A), the STI Office supervises multiple cross-government co-ordination processes in close collaboration with PACST, which offers expertise and a forum for engaging with various policy bodies and stakeholders. These processes range from the formation of the Basic Plan, the review of the sectoral mid-term and annual plans of sectoral ministries, and the annual budgeting review of strategic programmes and their monitoring and evaluation. A number of strategic documents (e.g. about

90 mid-term plans, as many annual action and monitoring plans, and more than 1 000 strategic programmes) are involved in these processes. Although the STI Office and PACST are selective, for instance, dedicating more attention to some key plans and programmes (in particular the new ones), the expansion of the volume of STI activities and of the number of programmes (which has grown even faster than the STI budget) may challenge the added value of the whole process in the future. The extent to which the STI Office and PACST can ensure the necessary strategic consistency of a growing scale and broadening scope of plans and programmes is an open question. While this is difficult to evaluate in practice, one illustration can be found in the agenda of PACST Deliberative Council meetings, which can include more than 12 mid-term plans to be reviewed. In addition, although the formal budget review process for the numerous strategic programmes takes only a month, the STI Office devotes an entire year to preparing for it.

This challenge has been dealt with in the past mainly through new laws that strengthened the mandate of the STI Office and new steering and monitoring mechanisms, which has increased the weight of these centralised processes. Given the extent of its whole-of-government co-ordination function, there have been proposals to position the STI Office above the ministerial level. However, there are concerns that the cyclical changes in high-level government bodies could disrupt its functions and continuity (KISTEP, 2021[26]).

5.3. Providing strategic directions to steer the Korean STI governance system

This section analyses in more detail the first level (see Figure 5.1) of the STI governance system in Korea, where STI strategic orientations are developed.

The key criteria for assessing the satisfactory performance of strategic steering mechanisms are:

- They should involve a relevant balance of top-down and bottom-up dynamics. Although the results of the deliberation on and selection of the priorities are most often formalised and conveyed by the highest level of policy making, it is a diffuse process that should embed the knowledge and preferences of multiple actors, from politicians and policy makers to experts and citizens. This ensures that different inputs (knowledge and expertise but also values and interests) feed into the formation of these strategies. It also creates more buy-in from these actors and, therefore, enhances their engagement in the ensuing resourcing and implementation of the strategies.
- Strategic policy directions should clearly define the desired endpoints to concretely guide public action. The different strategic documents and mechanisms at different time horizons (long-term, mid-term and annual plans) should be consistent and interlinked. They should also be anticipatory, i.e. factoring in knowledge about possible futures so that alternative directions and their potential impacts are explored.
- While being flexible to adapt to new conditions and evolving consensus, they should be stable and robust, extending beyond political terms to address ambitious and long-term challenges.

5.3.1. A cascading system of well-elaborated whole-of-government strategies

In the Korean system, high-level policy orientations are set in three main strategic frameworks: the long-term vision, the presidential programme agenda, and the five-year S&T Basic Plan. The latter is the most authoritative document, which aims to steer the interventions of policy bodies directly in charge of STI activities and all sectoral ministries and related agencies. This mid-term plan is well structured and includes objectives and quantitative targets that are monitored and serve as the basis for its evaluation when developing the next plan.

The long-term STI vision

Korea establishes long-term visions for S&T about every ten years. Previous visions include the Long-term Vision for S&T Development by 2025, launched in 1999, and the S&T Future Vision for 2040, launched in 2010. The current vision is Innovate KOREA 2045 – Challenges and Changes for the Future (hereafter, "Innovate KOREA 2045"), launched in 2020. The STI Office developed it following consultations with the line ministries and a dedicated ad hoc committee, the Future Strategic Committee 2045,[21] composed of around 20 experts from industry, academia and research institutes. The current vision aimed to create linkages between the former Going Together Hopeful Korea 2030 vision established in 2006 and the 2045 Vision for Innovative, Inclusive Growth announced in 2019, which, although both are economy- and society-wide visions, emphasises the important contribution of S&T to enhancing the sustainability and inclusivity of economic growth (MSIT, 2020[27]). These documents, which have a timeframe of between 25 and 30 years into the future, aim to provide long-term guidance for S&T mid-term strategies and plans, which are established every 5 years, particularly the S&T Basic Plans.

Innovate KOREA 2045 sets out the vision for the long-term desired orientations for Korean society and identifies the S&T challenges that must be addressed to realise the vision. Looking ahead to the next 25 years, it defines eight main "challenging tasks" that include both immediate issues (e.g. climate challenge, the COVID-19 pandemic) and those with a longer-term horizon (e.g. space exploration). In solving these tasks, the vision maps 16 "directions for technology development" along different time horizons, namely, short-term (within 5 years), mid-term (around 10 years) and long-term (over 20 years). Examples include autonomous robots for disaster relief, AI semiconductors, human space flights and brain-to-brain communication. The vision recognises that the government's traditional approach of selecting promising technology sectors is no longer effective in the fast-changing environment. Instead, it emphasises the government's role in identifying and presenting a blueprint of the key challenges of national importance and supporting various innovation actors to develop the necessary technologies and be at the forefront of innovation (MSIT, 2020[27]).

The eight challenging tasks are followed up with eight S&T "policy directions". One of these policy directions is, for instance, to shift from a fast-follower research model to a model of "challenge-led creative research". Another calls for a shift toward research to address social issues rather than "research to develop technologies". Other priorities include: supporting individuals in realising their true potential; exploring new types of government-industry partnerships to create markets; creating regional clusters and ecosystems; using S&T in the public sector; increasing the role of Korea as an international science and innovation leader in some areas; and using foresight to drive STI policy.

The presidential agenda

The presidential agenda provides broad directions for future reforms. For instance, the programme of the newly elected president includes 110 "policy tasks", including 7 that are directly under MSIT.

Some agendas that are not under MSIT also include items related to R&D and innovation.

The S&T Basic Plan

The S&T Basic Plan is an overarching strategic document that includes broad directions to guide all ministries, i.e. ministries in charge of R&I policy per se and sectoral ministries when they develop their STI strategies and plans in their respective areas. The Basic Plan is aligned with the presidential agenda (launched before the Basic Plan in the policy cycle) and sets more specific orientations for its realisation.

This overarching strategic framework, reflected in and complemented by area-specific strategies and plans, has driven and provided legitimacy for some important changes in the past. Notably, there was the turn to a post-catch-up STI system with a strong increase in basic research funding and related reforms. The overall increase of government-funded R&D expenditure of 150% in ten years from 2005 to 2015

(OECD, 2021[28]), leading to one of the world's highest R&D intensities, is another example of bold orientations taken by Korea. Proactive measures were also taken to support the emergence of new industries. One notable example is the support provided to the biotechnology sector since the beginning of the 1990s through the creation of specific R&D programmes in close co-operation with the private sector. This has resulted in significant growth and societal impacts in the form of domestic solutions to some health and ageing challenges.

Structure and content of the Basic Plan

The Basic Plans are structured along broad strategic directions and corresponding policy areas increasingly focused on solving societal issues, in line with the overall vision to build a more inclusive STI system. In contrast with most western STI strategies that only include objectives and targets, followed by an action plan in the best case, the wide orientations of the Basic Plans are complemented with more or less concrete "agendas" to be implemented by different policy bodies across the whole government structure.[22] Therefore, the Korean Basic Plans are both a mid-term strategic framework and a mid-term action plan.

The 5th Basic Plan was announced in 2022 and will cover 2023-27 in response to national societal challenges, such as technological hegemony, supply chain, climate change, digital transition and low birth rates. In line with these challenges, the 5th Basic Plan is structured around three main strategic thrusts and the necessity to keep strengthening national STI capacity in general:

- transforming the S&T system for qualitative growth
- strengthening capacity-building ecosystems for open innovation
- resolving national challenges and preparing for the future based on S&T.

To implement the policy directions, each strategic thrust includes a number of implementation projects (each of them containing five to seven detailed tasks and subsidiary action initiatives). The 5th Basic Plan also includes 12 critical technology areas and 50 core technologies, selected based on 3 criteria: supply chain and trade; emerging technology; diplomacy and security.[23] These technologies will receive enhanced support and investment from the government based on the strategy roadmap and R&D funding based on a mission-oriented funding distribution system. Efforts to strengthen international and private partnerships will also be intensified. Starting with advanced small modular reactors (SMRs) and quantum technology projects, ten projects are set to be launched in 2023.

Lastly, the 5th Basic Plan sets quantifiable targets for some important indicators. For instance, the objective for the share of the top 1% cited papers is set at 4.8% for 2022-26, a 1.27 percentage-point increase from 3.53% in 2015-19. An example of a similar target is the number of triad patents, which is set to increase from 2 057 in 2019 to 2 500 in 2027 (MSIT, 2022[29]).

Process for developing the Basic Plan

Developing the Basic Plan involves several consultation stages and concertation with a broad range of communities. It follows a multi-stage, multi-stakeholder process led by the Innovation Office, which begins before the presidential election with preparatory work by institutions such as the Korea Institute of S&T Evaluation and Planning (KISTEP) and the Science and Technology Policy Institute (STEPI). It includes an assessment of the realisation of the former plan and the provision of analytical support for S&T planning, notably through an analysis of changes in the overall context; a "policy demand" survey among STI institutions; and various forms of consultations with the main STI communities (universities and various types of research institutes, industry, and intermediary organisations, etc.). STEPI's Division for Strategy Research for Future Innovation also participates in this process.

The Planning Committee of the S&T Basic Plan, a specific ad hoc committee, is formed every five years by MSIT to support the ministry in planning the process for developing the Basic Plan. This committee supervises an elaborated planning structure, while the STI Office is responsible for drafting the plan. In the case of the 5th Basic Plan, a Co-ordination Committee of approximately ten members appointed by the Minister of Science and ICT develops the overall direction and collects feedback at the level of the overall plan. Divisional Committees (all composed of approximately 11 experts) develop the specific corresponding agendas for each of the four areas, as well as implementation strategies and detailed action initiatives. The four Divisional Committees are supported by several sub-committees focusing on specific issues (e.g. digital transformation or regional decline). Once a first draft of the plan is developed, PACST’s role is to approve the plan prepared by the MSIT and other ministries.

An evaluation of the outcomes and weaknesses of the last Basic Plan is also conducted every five years by MSIT with support from relevant organisations, such as KISTEP and STEPI, as part of developing the next plan.

5.3.2. The long-term consistency of strategic directions

A key issue in Korea and many other countries concerns the long-term orientation of the STI system. This has become important as countries face societal challenges which, like climate change, involve consistent efforts towards realising goals over decades.

While Korea’s "vision” can provide the long-term framework, it remains rather broad. The main strategic document is the Basic Plan, which serves as a reference for guiding resource allocation and monitoring STI interventions across the government. However, the Basic Plan is a mid-term plan that, moreover, can be, in principle, impacted by new government priorities set out in the presidential agenda. Although it is encouraging that there is political interest in and commitment to R&I, the need to adjust to new priorities every five years after a presidential election can cause discontinuity in the R&I governance and funding system.

Many governance systems strive to establish consistency between the short- to mid-term political and long-term STI policy cycles. One possibility is to organise a partial overlap between the political term and the STI strategic plan. This is, to some extent, the case in Korea, as the development of the Basic Plan starts about one year before the presidential election. Some countries have developed nested structures of long-term strategic and mid-term investment plans (Box 5.3).

Box 5.3. “Nested” long-term strategic and mid-term investment plans in Sweden and Norway

The Swedish Research and Innovation Bill

While budgets in Sweden are annual, a specific framework applies to the STI area to promote a more strategic and multi-annual programming process. The Swedish Research and Innovation Bill establishes strategic STI directions every four years to guide activities, implement concrete policy measures and allocate budget appropriations for the next four years. These appropriations are not formally binding, but a decision by the parliament stipulates that the funds can be earmarked for upcoming years. However, they can be recalled if there is a need to reallocate due to contextual changes. In practice, it has never happened.

The bill process, led by the Ministry of Education and Research, involves wide consultation every four years on policy needs. Important new policies are debated in this framework and announced in the bill with the reasoning behind proposals. For instance, the 2012 Bill included a new initiative meant to stimulate interactions within broad new configurations of industrial, academic and research institute actors by supporting the development of strategic innovation areas (SIAs). These SIAs were to be followed by selected Strategic Innovation Programmes run by the relevant community of actors themselves to implement the SIAs.

In the 2016 Bill, the government argued that four years was too short to allow long-term strategies and investments needed in this area to be carried out. Further, the R&I Bill had a ten-year perspective and included the government's vision for R&I in the coming decade. For instance, the 2016 R&I Bill covering 2017-20 included broad objectives for the ten-year period 2017-27. The goal for the research policy is that:

- Sweden shall be an internationally attractive country for investments in R&D. Public and private investments in R&D should continue to exceed EU goals.
- Research quality shall be reinforced overall, and gender equality shall increase.
- Engagement and societal impact shall increase.

These are, however, broad objectives that do not provide precise directions. Although there is no planned process, progress toward the stipulated goals is monitored at the end of each bill period.

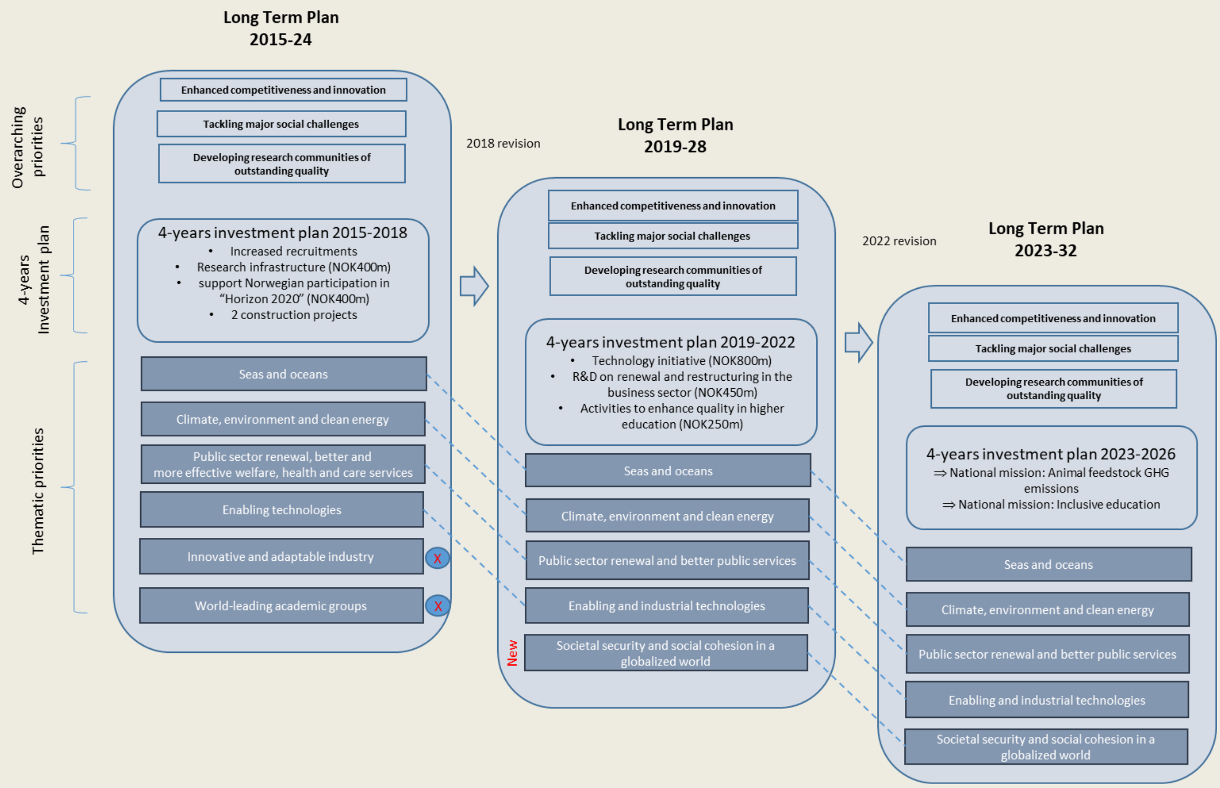
The 2020 Bill planned an appropriation increase of SEK 3.4 billion (Swedish krona) in 2021, SEK 3.2. billion in 2022, SEK 3.3 billion in 2023 and SEK 3.75 billion in 2024. Some of these funds will contribute to funding new national research programmes (in the areas of oceans and water, viruses and pandemics, mental health, digital development, crime, and segregation) and reinforcing existing programmes (in the areas of climate, sustainable community development, food, antimicrobial resistance, and working life).

The Norwegian Long-Term Plan for Research and Higher Education

In Norway, the Long-Term Plan for Research and Higher Education 2015-24 (hereafter, the "LTP") was launched in 2014 by the Norwegian government following a number of stakeholder consultations and inter-ministerial negotiations led by the Ministry of Education and Research. It covers research, innovation and, to a lesser extent, despite its name, higher education policy. The LTP is built around three overarching government objectives: developing research communities of outstanding quality; enhancing competitiveness and innovation; and tackling major societal challenges. It also includes specific objectives in priority areas (e.g. seas and oceans, climate environment and energy, public sector renewal, enabling technologies).

While the LTP has a ten-year perspective for designing longer-term avenues in broad terms, it includes a more precise four-year plan with financial commitments. Its revision every four years allows the government to add more concrete structural and programme-style policy activities to the LTP without changing the plan's general orientation. The new plan under development will cover 2023-32, with budget appropriations and concrete measures for 2023-26. The structure of the second LTP (2018 revision) was changed in order to better link the ten-year priorities and the four-year investment plan. In the latest revision of the LTP (2022), two national missions have been included in the plan (see Figure 5.6).

Figure 5.6. Norway's rolling long-term plan with national missions



Source: Based on OECD (2017[30]), *OECD Reviews of Innovation Policy: Norway 2017*, http://dx.doi.org/10.1787/9789264277960-en; OECD (2016[31]), *OECD Reviews of Innovation Policy: Sweden 2016*, http://dx.doi.org/10.1787/9789264249998-en; Swedish Research Council (2021[32]), "New initiatives in the Government's research bill that relate to the Swedish Research Council", https://www.vr.se/english/just-now/news/news-archive/2021-01-15-new-initiatives-in-the-governments-research-bill-that-relate-to-the-swedish-research-council.html.

5.3.3. STI strategies and plans in specific sectors and areas

Advisory and/or co-ordination committees active in other domains also provide advice on how STI could best contribute to achieving their mandates. This advice may come in the form of strategies and roadmaps. For instance, the National Economic Advisory Council has a sub-committee dedicated to innovation issues. Increasingly, committees are created to co-ordinate cross-cutting actions to tackle specific challenges, such as low fertility, ageing or climate change. By way of example, in 2021, the Carbon Neutrality and Green Growth Commission released two policy roadmaps to achieve Korea's net-zero emissions goal by 2050 (see below). Until 2022, the Presidential Committee on the Fourth Industrial Revolution also had a wide mandate with regard to all matters related to technologies such as AI, information and communications technology (ICT) and data technology (including in specific sectors or areas, e.g. smart cities or digital healthcare). Like the PACST, but with a different scope, it delivers advice and recommendations, co-ordinates policy measures submitted by various ministries, organises public campaigns, prepares related regulatory and institutional reforms and fosters ecosystems for new "Fourth Industrial Revolution" industries.

In order to tackle fine dust pollution, the National Council on Climate and Air Quality (under the President of Korea; now disbanded and reorganized into the above-mentioned commission) provides advice to the Special Committee on Fine Dust (under the Prime Minister; committee with public-private membership), which has a mandate to co-ordinate actions and take decisions. This committee supports the development and validates the cross-ministerial Comprehensive Plan on fine dust control, which is taken up by sectoral ministries in their respective policy field. MSIT, for instance, develops an R&D plan on fine dust.

While the Basic Plan is meant to be the highest-level strategic document in the area of S&T, important ones are also set by MOTIE to guide business innovation: the Industrial Technology Innovation Promotion Plan and Industrial Convergence Basic Plan (every five years since 2011, currently under its seventh edition covering 2019-23) (MOTIE, 2019[33]).[24] Although the Industrial Technology Innovation Promotion Act calls for effective connections with the Basic Plan, the link between these plans for industrial technologies and the Basic Plan is unclear. In principle, the consistency between these strategic strands is ensured by the review of MOTIE's plans by PACST and directly by the STI Office, which is tasked with co-ordinating the different plans. However, there is no formal mention of the Basic Plan in the industrial technology plans. Like in many countries, the limited connections between the two plans reflect co-ordination issues between authorities in charge of science and business innovation. In Korea, the MSIT is mandated by law to co-ordinate and steer all policy matters related to S&T (including in industry) via the previously mentioned Framework Act on Science and Technology. The Industrial Technology Innovation Promotion Act provides MOTIE with a strong responsibility to lead the development and commercialisation of industrial technologies in a country where industrial innovation plays a key role in national growth and competitiveness.

Other plans provide strategic guidelines for R&D in energy, transport and agriculture, among others. Some plans (such as the one by the Ministry of Land, Infrastructure and Transport [MOLIT]) have a ten-year horizon and are revised every five years.

5.3.4. Foresight is well connected to agenda setting and policy making but remains too focused on technology forecasting

Korea has traditionally been at the forefront of foresight, with a strong focus on technology forecasting. It has not only devised new methodologies and tools but also ensured that their results are used to inform strategic decisions, notably in the context of the Basic Plan development process. Foresight systematically informs whole-of-government and sectoral strategies and plans. These exercises create opportunities to debate and make better policy decisions, especially where these involve societal judgements or that have a systemic character. Foresight is particularly well connected to the process of developing the S&T Basic Plan.

The government has established and mainstreamed formal processes to ensure the linkages between STI foresight and mid- to long-term strategy. The first major foresight exercise was run in 1994, and so far, six exercises have been undertaken.[25] Since then, foresight has become more systematic and formally integrated into strategic planning. Foresight plays an important role in informing the Basic Plan about recent changes in the domestic and international environment, devising scenarios about future technologies and deriving options for future mid-term and long-term evolution of Korean society and implications for STI priorities. The cycles of S&T foresight and Basic Plans are aligned, and a formal procedure, starting two years before the launch of the Plan, connects the two processes. Against this backdrop, the 4th Basic Plan was backed by the 5th S&T Foresight exercise (2016-2040), including Horizon scanning, a Delphi survey, scenario planning and technology tipping point analysis. The 6th S&T Foresight exercise in 2020-21 analysed the future trends from 2021 to 2045.

To this end, the MSIT formed the Foresight Executive Committee to review and co-ordinate foresight activities in collaboration with the Future Scanning Committee and the Future Technologies Committee. KISTEP is in charge of the general management of the entire process and provides support to these committees.

Foresight is implemented following a two-stage process:

1. The Future Forecast Committee and the Future Technology Committee operate a series of steps, including trend analysis using, notably, the STEEP (Social, Technological, Environmental, Economic and Political) analysis and domestic and foreign future outlook reports. The 6th Foresight exercise identified 5 megatrends, 12 trends and 62 major issues expected to considerably impact Korea's socio-economic prospects.
2. In a second phase, the Future Forecast Committee and the Future Technology Committee identified 241 technologies expected to emerge by 2045. The committees then conducted a two-round Delphi survey addressed to S&T experts to assess the potential impact and the corresponding societal and policy tasks to perform. Finally, based on the previous survey results, a tipping point analysis was conducted among members of the Future Technology Committee to identify 15 major future innovative technologies expected to have a considerable socio-economic impact when they are diffused in society in the future. The 6th Foresight exercise concluded that all 15 technologies are expected to reach their tipping point first in the United States.

The foresight exercises increasingly take into account societal trends, especially during the first review stage, and are well connected to the agenda-setting process. Nevertheless, the exercise culminates in a set of technological guidelines and the identification of future technologies with a forecasted diffusion timeline. While Korea is moving in this direction, the recourse to systemic, societal and human-centric exercises, including developing future visions regarding societal evolution, could be strengthened to help reflect on and design policies to support sustainability transitions.

Foresight, technology assessment and other types of analytical support for strategy and policy making are most often co-ordinated if not performed by the social science GRIs attached to the Prime Minister's Office or other research institutes. KISTEP (under MSIT) and, since 2021, STEPI have served as the secretariat of the Divisional Committees that deliver the content of the three strategic thrusts of the Basic Plan. The Korea Development Institute is one of the main providers of advice for the Blue House. The Prime Minister's Office also maintains the Korea Institute for Industrial Economics and Trade (KIET), a think tank that focuses more on economics and innovation, in line with the ministry's mission.

More generally, these research institutions and think tanks provide strategic intelligence to the ministries in their respective areas. KISTEP, for instance, supported the consultations during the preparation of the 2021 Innovation Act (see Box 5.1.). It held a number of legislative discussions in regions, conducted meetings with ministries and collected opinions from R&D actors to support the deliberation of the National Assembly.

More generally, various institutions (in particular, KISTEP and STEPI) provide strategic intelligence on science, research and innovation through foresight, planning and evaluation work.

5.4. Planning and budgeting STI policies across the government structure

This section analyses the second level of the STI governance system dedicated to policy co-ordination and planning (Figure 5.1). At this level, governance aims to ensure the alignment and consistent funding of STI public interventions implemented by policy-making institutions covering different policy fields and/or levels of government. The mechanisms for doing so greatly differ between countries as they are deeply embedded in the budgetary processes and various institutions where ministries can interact. The main differences between the different systems are the level of centralisation/decentralisation of the co-ordination tasks; the extent to which these mechanisms are systematic or depend on opportunities and goodwill; and their time frame (annual or multi-annual).

The key criteria for assessing the satisfactory performance of planning and budgeting mechanisms are:

- They should effectively connect the overall strategic STI priorities to the concrete implementation of programmes and policies across the government structure.

- They should result in securing and allocating resources among different policy-making institutions, such as ministries and agencies, that are commensurate with the importance of STI activities in achieving national priorities and addressing key challenges.
- They should allocate the responsibilities across the government structure in line with ministries' portfolios while eliminating unnecessary overlaps and promoting co-operation between different policy-making institutions where relevant.
- These mechanisms should be performed with minimal transaction costs and conflicts.

5.4.1. Korea's process to reflect its long-term strategic orientations in its mid-term and annual action plans across the whole of government remains too formal and mechanistic

This section describes the various steps of the programming and budgeting process in more detail.

The development and review of mid-term action plans

Korea has several formal procedures to ensure that the Basic Plans orientations concretely guide the programmes and activities of all ministries with R&I activities. Sectoral ministries are required by law to integrate the Basic Plan priorities into their mid-term plans, which are reviewed and monitored centrally by the STI Office and PACST.

In line with the Framework Act on Science and Technology, each ministry submits to MSIT (in practice, to the STI Office within MSIT) a mid-term action plan that provides an overview of the new and ongoing programmes and activities to be implemented in the coming five years. MSIT is tasked with reviewing these mid-term plans (under the name of "Mid- to long-term plans survey and analysis"),[26] notably to check whether they align with the Basic Plan and do not overlap with other ministries' plans. The STI Office can interact directly with the ministries when changes are needed.

This review of mid-term plans has been carried out every year since 2008, as all – new and ongoing – plans are sent to the STI Office. The number of submitted mid- to long-term plans varies each year within the 80-120 range. In 2020, there were 90 plans from 16 central government bodies (12 ministries, 3 administrations, 1 commission), of which 44 came from MSIT, followed by 11 from MOTIE, and 9 from the Ministry of Agriculture, Food and Rural Affairs (MAFRA). Given the difference in timelines for these plans, 15-20 are reviewed annually. Some of these plans concern specific technologies and industry developments, such as the National Strategy for Artificial Intelligence (2019-2030) of MSIT and the Comprehensive Plan on Environment and Health (2011-2020) of the Ministry of Environment.

At the end of the review process, MSIT delivers a list of recommendations that may require the ministries to amend the plans and should be taken into account in their annual action plans. Every year, the results of this review are transmitted to the PACST Deliberative Council for validation and notified to MOEF and other ministries.

The five-year R&D Investment Strategy[27] is an important new step in this process to better bridge the S&T Basic Plan and the sectoral ministries' mid-term plans. The STI Office delivered the first one in February 2023. Although it does not include budget figures (only determined yearly), the R&D Investment Strategy sets some indicative five-year R&D budgetary or spending targets for investments in specific technologies. The strategy is also more actionable than the Basic Plan and aims to facilitate the five-year programming by the sectoral ministries and the "consistency check" by the STI Office. Therefore, this document aims to be the missing link between mid-term strategic orientations and mid-term planning. For this reason, the five-year R&D Investment Strategy must be finalised within 90 days from the establishment of the Basic Plan, and the annual action plans are confirmed until the end of January every year (KISTEP, 2021[34]). This new process is too recent to assess its effectiveness, however.

The development and review of annual action plans

The formal link to policy implementation is ensured each year by the development of an action plan by the STI Office to guide ministries' annual programme proposals.

In line with the Framework Act on Science and Technology, all relevant ministries and agencies provide the STI Office with their Annual Plan for the Basic Plan. This report presents their actions undertaken in the different strategic thrusts of the Basic Plan, the outcomes of these activities and their plans for the coming year. The STI Office integrates these inputs into an annual Basic Plan submitted to PACST's Management Committee under the Deliberative Council for review. This plan is both a monitoring (activities of the past year) and an action plan (activities planned for the next year) covering the whole government structure. It does not include budget figures. In addition, some sectoral ministries develop and submit annual plans and submit them to the PACST's Deliberative Council via the STI Office.[28] The latter encourages this practice.

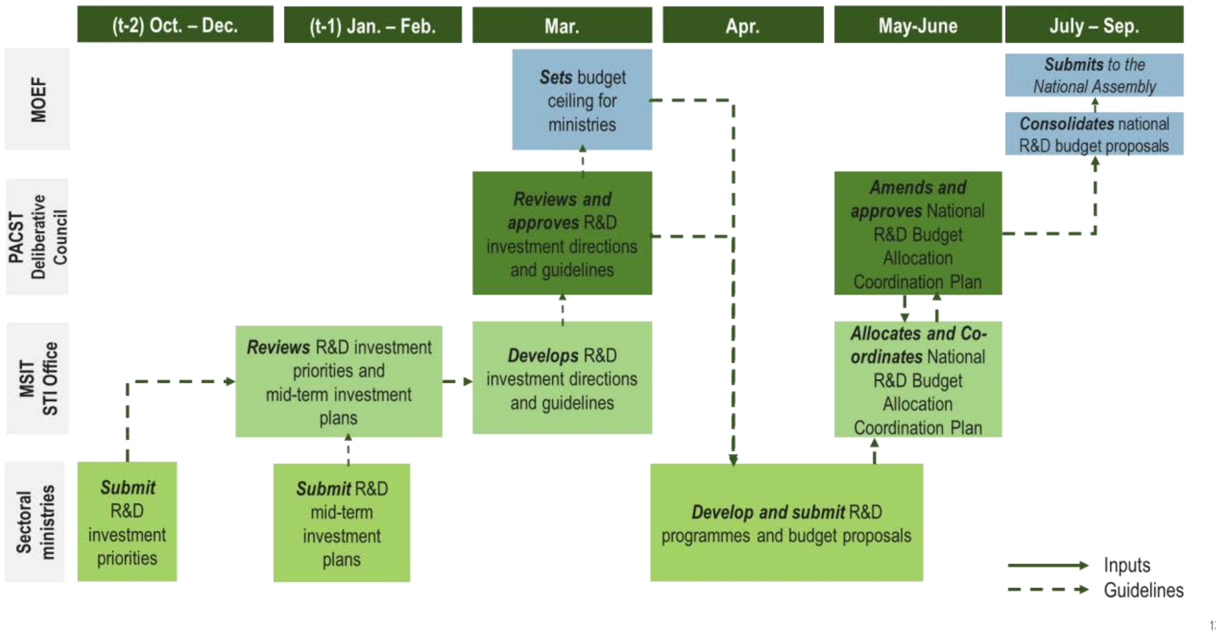
5.4.2. A comprehensive process for the annual cross-ministerial co-ordination of STI budgets

A comprehensive process is in place to determine the overall R&D budget and allocate it among the different ministries while adhering to the budget threshold set by the MOEF for each ministry. This process involves a review of a number of Strategic Programmes.

Overview of the annual budgeting and programming process

As shown in Figure 5.7, the annual budgeting and programming process starts in the fourth quarter of the year t-2 (year minus two) with the submission by ministries of their informal and broad priorities for the year after next (in two years). Based on these inputs, the STI Office provides guidance on the year t-1 (year minus one) for the next year's programmes and ministries' budget requests (called the "R&D investment directions"). The R&D investment directions are also used to inform the overall budgetary indications. After R&D budget ceilings for each ministry are set by the MOEF (usually at the end of April), based on these maximum budget allocations, all ministries develop their R&D programme proposals (until the end of May) in consultation with their own committees (for instance, the General Energy Committee that advises MOTIE) and networks of stakeholders for the next year. These proposals comprise the continuation of ongoing multi-annual programmes and some new programmes. All R&D programmes are submitted for review to the STI Office. Both the content and the budget requests of these programmes are reviewed before being approved by the Deliberative Council. The revised proposals are transmitted in the form of the National R&D Budget Allocation and Co-ordination Plan[29] to the MOEF for the final decision on the programmes and their respective budgets. Once aggregated, the MOEF transmits the government's annual R&D budget to the National Assembly, which approves it 30 days before the beginning of December of the year t-1.

Figure 5.7. Overview of Korea's annual budgeting and programming process



Source: OECD based on desk research and stakeholder interviews and KISTEP (2021[35]), *Government Research and Development (R&D) Budget: FY 2021 (2021년도 정부연구개발예산 현황분석)*, https://www.kistep.re.kr/board.es?mid=a10305080000&bid=0002&act=view&list_no=42194&tag=&nPage=1 and STEPI (2021[36]), *Background Paper for OECD Reviews of Innovation Policy: Korea 2021 (provided by STEPI to OECD)*.

The annual review of R&D programmes

A key milestone in the annual budgeting cycle presented above is the central review of all R&D strategic programmes from around 26 ministries and departments. This process applies to the major R&D programmes (i.e. mainly science, technology, engineering and mathematics [STEM]-related programmes),[30] which accounted for about 80% of the total R&D budget in 2022. Programmes related to social science and humanities (general R&D programmes) are managed directly by the MOEF. The extent to which this divide between two strands of co-ordination might limit the ability to better integrate natural sciences and social sciences and humanities is not known. One can surmise that it does not promote the launch of transdisciplinary research programmes, i.e. programmes that involve integrating knowledge from different hard and soft science disciplines and (non-academic) stakeholder communities. This issue is increasingly important as transdisciplinary research is considered crucial to dealing with complex societal challenges (OECD, 2020[37]). Such integration is to be realised primarily at the level of projects and programmes themselves by agencies and ministries. However, it should also be reflected at a higher level in the system and encouraged by mechanisms to identify co-operation opportunities.

The STI Office reviews the R&D-specific programmes with support from eight expert committees under the Management Committee. The PACST Deliberative Council reviews and approves the final results of this process. These expert committees comprise about 20 scientific and technological experts from the public and private sectors in specific areas (energy, ICT, and convergence technologies, among others). These experts assess the technical soundness and feasibility of the different programmes submitted by the ministries. These assessments are complemented by the STI Office's analysis of the coherence of the different programmes, both between themselves and with the priorities outlined in the Basic Plan. On this basis, the STI Office provides feedback to the ministries, which can then revise their proposals. If needed, there can be meetings between the STI Office and the relevant services of the ministries to discuss the details of the revisions to be made. In some cases, the STI Office can provide additional budgets to some programmes if deemed necessary, although such practice is relatively rare. In the end, once the decisions regarding budgets of the different programmes for one ministry are aggregated, they can represent an increase or decrease in the ministry's R&D budget.

It is beyond the mandate of this OECD review to assess the level of resources required by this process in relation to its benefits. The STI Office contends that this process remains light and does not consume significant resources.[31] First, the review process is more detailed for new programmes than ongoing ones. The STI Office also focuses on key strategic programmes, i.e. those most relevant to the government's priorities and/or are the largest in allocated public funds.

However, one issue concerns the sustainability of this process in the future. The process is essentially the same as when the Framework Act established it in 2001. In 2003, the NSTC reviewed 234 R&D programmes submitted by 19 ministries and agencies, with 142 civilian experts joining the review process. In 2020, the STI Office and the Deliberative Council expert committees reviewed 949 programme proposals, including 253 new ones. In 2021, they reviewed 1 198 programme proposals, including 291 new ones, and 1 254 programme proposals in 2022 (196 new) (MSIT, 2020[38]; 2021[39]). The trend is expected to continue due to the R&D budget increase and ministries' inclination to divide large projects into smaller ones to avoid the pre-feasibility test (see below). The increase in the number of programmes to be reviewed may, in the future, require more resources and potentially lead to a procedural mechanism with reduced value. Therefore, it is essential to allocate resources to STI Office activities that operate at a more systemic and strategic level, in close co-operation with sectoral ministries. The new five-year R&D Investment Plan aims to enhance the strategic dimension of budgeting. Evaluating whether this new mechanism has achieved the intended outcome will be crucial.

Regarding the results of this process, the STI Office reports that the guidance it provided at the beginning of the cycle (see Figure 5.7) in 2022 allowed ministries to save KRW 1.3 trillion. Another KRW 1 trillion was saved by eliminating duplications between programmes. After identifying overlaps, the STI Office encouraged the ministries concerned to reorganise their programmes. The central co-ordination of R&D programmes therefore resulted in significant efficiency gains, representing about 9.3% of the overall 2023 R&D budget (KRW 24.7 trillion, about EUR 18.8 billion) (Government of Korea, 2022[40]). The funds saved are reinvested in R&D programmes. The STI Office can indeed offer budget top-ups to certain programmes that are deemed strategic.

One strength of the Korean system is that the sectoral ministries interact with STI-specific organisations (the STI Office and the Deliberative Council) with expertise in this policy field, while in most other countries, the finance authorities keep their main budgetary prerogatives. The need for specific R&I expertise was one of the main reasons for the delegation of the budget formation function to the STI Office and Deliberative Council in the first place.

Beyond the number of programmes being reviewed, the granularity of the review is a critical issue. Although in English, everything appears to be at the "programme" or "project" level,[32] the Korean language demonstrates a nested structure with distinct programme levels. There are five main levels, as shown in Annex Table 5.B.1. This configuration is based on the Programme Budgeting System that was put in place in 2008. The goal was to align the organisational structure of ministries with the classification of R&D programmes and projects, allowing for more strategic management of R&D support at a higher level in the administrative structure. Against this backdrop, the higher-level groupings of "1" and "2" were created to match the bureaucratic units of office and department[33] within ministries (KISTEP, 2019[41]).

The *ex ante* review of programmes is performed at the third level of Specific Programmes, which represent rather small administrative entities. However, this can vary significantly from one case to another. A survey conducted as part of a study in the bio-health area revealed that the budget review process is focused at a level that is too detailed, rather than at the programme (level 1) or programme unit (level 2) levels, which would be more appropriate for more holistically assessing the relevance of government actions in addressing overall national priorities (Lee et al., 2020[42]). It is, however, essential to link large strategic orientations and activities implemented in projects and other types of initiatives. While lower-order levels are relevant to reduce overlaps and increase management efficiency, this should be embedded in strategic discussions about what to do for what impact, by whom and with whom. Such reflection is conducted as part of the development of the Basic Plan and the review of the mid-term plans of all relevant ministries, which both set the broad strategic orientations. However, the linkages between these overall strategic orientations and the budgetary review of programmes should be strengthened. The mid-term plans previously discussed partly provide this holistic and higher-level perspective, but it is important to complement these with continuous strategic steering and monitoring.

5.4.3. The stringent pre-feasibility test of large R&D programmes has been improved

The pre-feasibility test, which conditions the launch of large programmes, can potentially prevent the misuse of significant budgets. Such *ex ante* assessment of large programmes already existed, but it was administered by the MOEF, like for any other "big projects", such as those in construction. The STI Office now leads a dedicated test for R&D projects. Large programmes with total expenditures over KRW 50 billion (approximately EUR 36 million) and public support of more than KRW 30 billion must undergo this pre-feasibility test, which is a two-stage process divided into a pre-test and a main test in order to avoid a waste of administrative efforts (Ministry of Legislation, 2021[43]).

The first stage pre-test is based on four criteria: 1) necessity and urgency considering recent S&T developments; 2) appropriateness to be funded by the national R&D budget; 3) novelty, yet having foreseen linkages with the existing programme; and 4) specificity of the programme plan. These criteria are reviewed using ten sub-indicators (KISTEP, 2021[44]).

If the programme successfully passes the first stage, the main test is then carried out in about seven months. The assessment of the main test uses three high-level criteria with mid-level indicators:

- **S&T feasibility**: Three mid-level indicators evaluate the adequacy of the "context of the identified problem/issue", the "programme goal", and the "specific tasks and implementation strategies".
- **Policy relevanc**e: Two basic mid-level indicators examine the "consistency with existing policies (namely, high-level strategies)" and "risk factors (including financial and legal aspects)". If the programme concerns wider matters outside the conventional STI policy arena, such as balanced regional development, job creation or safety assessment, it may be selectively scrutinised with one additional "special" indicator.
- **Economic feasibilit**y: Cost-effectiveness analysis (E/C; if quantification is not possible but at least comparative alternatives exist) or cost-benefit analysis (B/C; if the programme's effect can be quantified) is performed, and the results of the analyses are presented along with the total project cost estimate.

The STI Office is entrusted with forming the General Committee for National R&D programme evaluation under MSIT. The experts of this committee perform the assessment. In 2018, this exercise was reduced from one year (on average) to six months. In the following years, the criteria for reviewing these large programmes, based on procedures already in place in other areas, were modified to be better suited for R&D projects (Table 5.3). Specific methodologies apply to programmes with which R&D correspond to three pre-defined profiles: challenging, growth and infrastructural. For instance, the challenging R&D programmes are reviewed using the cost-effectiveness analysis rather than the more traditional and narrower cost-benefit analysis. Furthermore, decisions now include explanations and rationales, which enables ministries to learn from the assessments and improve their programme designs accordingly.

The feasibility test is very stringent: only 15% of submitted large programmes pass the pre-test successfully, and 52% of the programmes that pass the pre-test succeed in passing the main test.[34] This leads ministries to reduce the size of their projects or split them into several programmes to not exceed the KRW 50 billion threshold. These avoidance strategies result in increased transaction and management costs and possibly in reduced effectiveness of sub-scale programmes.

Table 5.3. Modified evaluation criteria of Korea's pre-feasibility test (as of 2019)

High-level criteria	Mid-level indicator	Low-level indicator	Weighted value by programme type (%)		
			Challenging type	Growth type	Infrastructural type
S&T feasibility	Adequacy of the context of the identified problem/issue	-	55-65	40-50	40-50
	Adequacy of the programme goal	-			
	Adequacy of the specific tasks and implementation strategies	-			
Policy relevance	Consistency with existing policies	Compatibility with high-level national strategies	20-40	20-40	30-50
		Implementation structures and institutional will			
	Risk factors	Financial			
		Legal and institutional			
Economic feasibility	-	-	Less than 5	10-40	10-20

Source: Information provided by STEPI.

MSIT has recognised this issue and plans to raise the threshold to KRW 100 billion. This process should be reviewed in one year to assess the result of this change and, more generally, its overall added value and unintended effects.

5.5. Implementing and evaluating STI programmes and projects

This section describes and analyses how, at the end of the policy cycle, the governance arrangement allows strategic orientations and related programmes and plans to be put into action through various types of instruments and regulations and monitors and evaluates their effects. It does not cover the whole Korean policy mix. The components (policy instruments and initiatives) pertaining to business innovation and knowledge creation are analysed in Chapters 3 and 4, respectively.

The key criteria for assessing the satisfactory performance of implementing and evaluating STI programmes and projects are:

- Appropriate incentives and governance arrangements are set to ensure that agencies are steered towards desired goals through strategic orientations and action plans while maintaining autonomy in how they choose to realise them.
- The objectives and rationales of the different policy instruments are clearly linked to the high-level strategic frameworks and the different ensuing ministry and agency plans.
- These instruments realise their respective goals but also, when relevant, contribute to systemic objectives. In some cases, they can be articulated or even jointly managed and implemented.
- There are mechanisms, regulations and "safe spaces" in place to allow for the experimentation of new approaches.
- Monitoring and evaluation results feed into decision-making processes.

5.5.1. There have been significant efforts to improve and harmonise the key role of agencies in implementing R&D programmes

STI policies are mainly implemented in the form of R&D programmes by around 15-17 dedicated R&D agencies.[35] These agencies can be mandated to allocate funding and manage projects (R&D management agencies), while others perform a range of other actions to support R&D and innovation (R&D promotion agencies). In some cases, the difference between the agency roles is unclear, with some agencies playing both. Furthermore, some agencies have the title of institutes, such as the Institute of Information and Communications Technology Planning and Evaluation (IITP), which promotes technology transfer in the IT sector and manages national R&D projects/programmes funded by MSIT.

Through the years, management agencies have established a set of elaborate programme management procedures throughout the whole project cycle. As in other advanced countries, these agencies are tasked with defining the precise programmes under the purview of their line ministries. Once approved and funded through the annual process described above, they develop roadmaps and calls for proposals, involving various experts and stakeholders (notably through the use of surveys and expert committees) to organise the project selection process. The projects are then funded, managed, monitored and evaluated. They have well-established processes for performing these tasks. Within agencies, the programme directors are important actors, responsible for consultation with stakeholders and managing the portfolio of projects in their respective areas.

The programmes and the projects within are multi-annual. At MOLIT, for instance, projects are funded for three to seven years, depending on their objectives, with a majority being funded for five years. Moreover, as previously mentioned, respective R&D agencies are subject to different mandates that are formalised in a number of laws and decrees accumulated over time. In this regard, enacting the 2021 Innovation Act helped streamline the overall process in that the act applies to all national R&D programmes and projects and takes precedence over other laws and regulations of sectoral ministries (MSIT, 2022[45]).[36]

As previously mentioned, the Innovation Act includes new provisions for regular reviews of agencies by their respective "principals". Research institutes and project investigators are required to submit annual, mid-term and final progress reports, as well as performance reports upon request from the heads of central government bodies (e.g. ministries). The Innovation Act specifically outlines the content to be contained in these reports, along with the timing. For instance, the final report should be submitted within 60 days from the termination of projects and should provide information on: the performance level; the level of goal achievement; the contribution of the project to related fields of research; and future plans to manage and utilise the outputs (MSIT, 2022[45]). Furthermore, the Innovation Act clarified the regulations for performance evaluation. The most notable change is that both the process and achievements of the R&D projects are evaluated simultaneously, whereas, before the reform, the assessment of results preceded the review of the process. This reform applies to both the mid-term and final evaluations.

5.5.2. There are no effective governance arrangements to link agencies' funding to their performance and strategic goals

Although their scope, status, functions and even name (agency, council, foundation or institute) vary among countries, the term "agency" generally refers to semi-autonomous organisations that programme, select and fund research and/or innovation activities under the ministry that has authority in their policy area and has a budget to fulfil this mandate. In most countries, agencies allocate specifically project-based funding through competitive mechanisms that respond to well-accepted international norms regarding project selection and evaluation (while ministries often retain the function of allocating institutional funding to higher education institutions and/or research institutes) (Borowiecki and Paunov, 2018[46]).

R&D management agencies in Korea are essentially execution agencies that plan, manage and evaluate projects in line with the strategic orientations set by their ministry. The type of governance arrangement established between the "principal" and its agency is therefore essential to ensuring effective bi-directional information channels:

- Incentives set by the ministry should convey clear messages on priorities and objectives, guide agencies in performing according to these objectives, and hold them accountable for their performance.
- Information feedback loops from the agency to the ministry ensure that the latter sets relevant objectives based on data collected by agencies as part of their management activities (notably results from the monitoring and evaluation, but also the information retrieved and the expertise formed in the numerous consultations conducted during programme planning and diverse road-mapping exercises).

In many countries, these governance arrangements have evolved toward ministries defining objectives while giving agencies increased autonomy to devise the best ways to meet these objectives. Normally, therefore, ministries do not make decisions about individual projects.

In Korea, although the proximity to the principal is always a matter of balance, agencies appear very close to their relevant ministries. They interact frequently, for instance, during consultations with R&I-performing organisations (brainstorming and road-mapping workshops, etc.). This proximity provides better information to the agencies, which is essential as policy implementation often extends beyond the usual scope of authority of the R&D agency, especially when addressing systemic societal challenges involving issues such as regulations or market incentives. However, this proximity should not reduce the operational autonomy of the agency, and it should have the freedom to implement what it considers to be the best mechanisms to meet the set objectives.

More importantly, the governance arrangements in place do not connect the agency's strategic orientations and performance to the funding allocated by the relevant ministry each year. Although evaluations of the agencies by MOEF use the mid-term plans submitted by the heads of agencies when taking office as a basis, conducting the evaluations annually hinders the inclusion of more strategic considerations about mid-term impacts. Furthermore, the results of these evaluations are only linked to the salary of the agency head and not to the agency's budget itself (Hwang, Park and Kim, 2021[47]). Implementing a clear performance framework to allocate funding offers several benefits:

- The performance framework set by the ministry trickles down within the agency and, therefore, also incentivises different agency departments.
- Rather than a multitude of daily interactions, it sets conducive conditions for strategic discussions between the ministry and its agency on the agency's objectives and the means needed to fulfil them.

Internationally, most research funding and performing agencies are separated organisationally from their line ministry (operating "at arms' length") and may be governed via multi-year performance agreements. For example, in France, the National Research Agency (ANR) is governed by four-year performance contracts negotiated with the Ministry of Higher Education and Research. The contract defines the objectives, actions (with a timeline) and monitoring indicators for the agency. The current contract, covering 2021-25, includes 19 indicators and 37 milestones describing the key actions to implement to realise the agency's 6 overarching objectives. Based on this contract, the ANR develops three-year action plans spanning two contracts (ANR, 2021[48]).[37] This ensures continuity between two contracts while still allowing for changes. By way of another example, Austria implements a comprehensive approach to steering its agencies and other central institutions operating under the purview of ministries (see Box 5.4).

Box 5.4. Connecting a national strategy to agency priorities, activities and funding: Austria's Research, Technology and Innovation (RTI) Pact

Austria's ten-year government strategy, the Research, Technology and Innovation (RTI) Strategy 2030, adopted by the Austrian Council of Ministers, outlines the nation's top priorities. It is structured along three objectives and eight interlinked and interdependent "fields of activity" (each field of activity is assigned to one objective but can contribute to several of them). The strategy was significantly influenced by the conclusions of the *OECD Reviews of Innovation Policy* conducted in Austria in 2018. Its implementation is monitored by a cross-governmental RTI Task Force under the chair of the Federal Chancellery, involving authorities in charge of finance, education, science and research, digital and economic affairs, as well as the Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK).

To connect the overarching national strategy to concrete activities on the ground, the Austrian government decided in 2020 to negotiate priorities every three years based on the Research Financing Act between the three ministries with the highest R&I budgets (the Federal Ministry of Education, Science and Research [BMBWF], the BMK and the Federal Ministry for Digital and Economic Affairs [BMDW]). In a cross-ministerial setting, the 2021-23 RTI Pact (hereafter, the "Pact") operationalises the targets and fields of activity set out in the RTI Strategy 2030 and defines the corresponding priorities and concrete measures to be implemented for the coming three-year period. The Pact also establishes a multi-annual stable funding framework (amounting to EUR 3.9 billion) and reduces duplications between the three ministries.

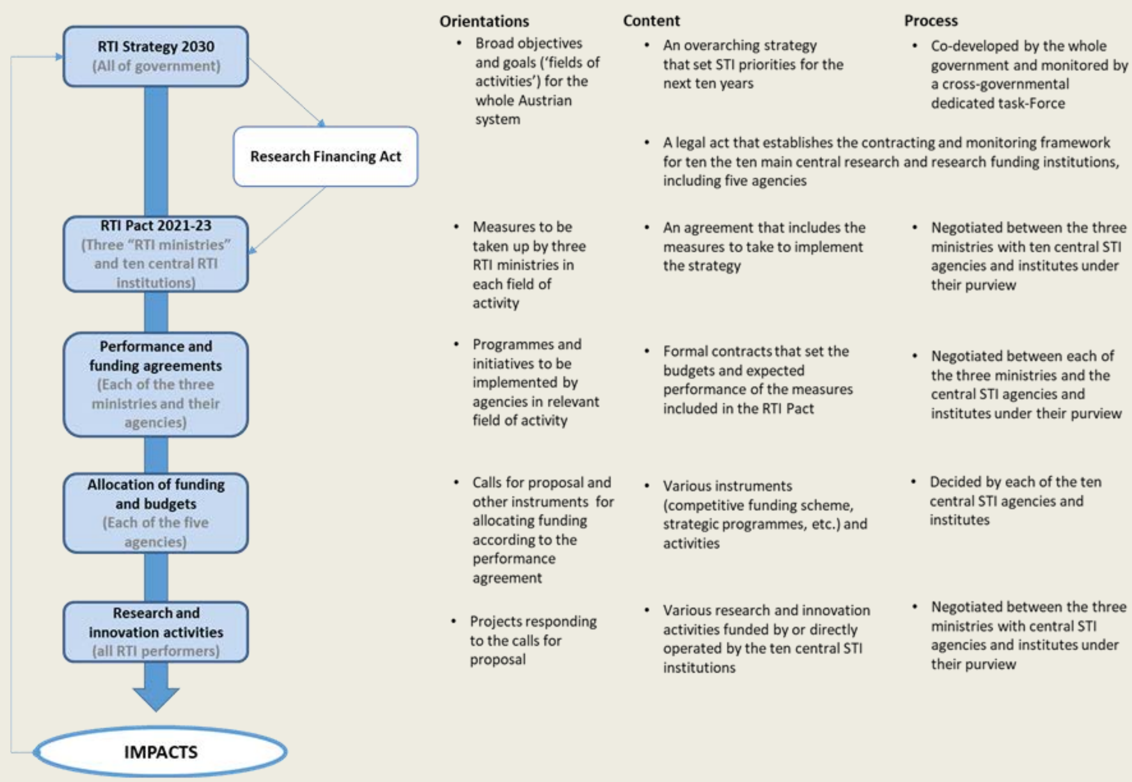
Concretely, the Pact is a 20-page document structured along the RTI Strategy 2030's field of activities. For each field of activity, the Pact presents a list of measures to be implemented. The precision of these measures enables the communication of the expectations for the desired results while leaving room for agencies to determine the best way to implement them. For instance, the field of activity "Promote excellence in basic research" (assigned primarily to Objective 2, "Focus on effectiveness and excellence") includes four measures, including the establishment of performance agreements with universities and the central institutions for basic research specified in the Research Financing Act with a focus on excellence and appropriate competitive mechanisms for the internal allocation of funds. Another measure calls for developing and testing new, innovative types of instruments and measures for funding excellent research that may also be high-risk and targeted use of open innovation and citizen science methods to identify research questions of relevance to society. In the same objective, the field of activity "RTI for achievement of the climate targets" includes a measure that calls for the adoption of mission-oriented funding programmes, which can make a significant contribution by pursuing a co-ordinated, cross-sector approach, keeping regulatory frameworks in mind and responding to the needs of stakeholders.

Another important component of this governance structure is the Research Financing Act passed in July 2020, which establishes a specific legal basis for financing the ten non-university central research and research funding institutions, including the five agencies active in the R&I area. The objective is to allow multi-year strategic funding of these institutions through the negotiation of performance and funding agreements between them and their ministry of reference, in line with their mandate and scope. For instance, the funding agreement (Finanzierungsvereinbarung) between BMBWF and the Austrian Science Fund (FWF) for 2021-23 refers formally to the measures included in the Pact that the agency's programmes will contribute to. In accordance with the legally assigned tasks according to the Research and Technology Promotion Act (FTFG), it includes a description of the different programmes, the budget assigned to these programmes for the three years, as well as monitoring and governance arrangements.

The Research Financing Act also sets out a framework for the annual monitoring of the use and effect of their allocated budgets. An annual report provides a systemic overview of these ten institutions based on eight standardised indicators. At the end of the term of the performance and funding agreements, a report will present a comparative analysis of these institutions' budgets and actual outcomes.

The Pact is, therefore, a new element added in 2020 to the Austrian governance structure that enables a clear and formal strategic continuity between the ten-year STI strategy and the activities of research-performing organisations funded by agencies (see Figure 5.8).

Figure 5.8. Overview of the strategic continuum across the different layers of Austria's STI system



Note: The five agencies are the Austria Wirtschaftsservice Gesellschaft mbH (AWS), the Christian Doppler Research Association (CDG), the Austrian Science Fund (FWF), the Agency for Education and Internationalisation (OeAD) and the Austrian Research Promotion Agency (FFG).

Source: Based on Austrian Federal Government (2021[49]), *Austrian Research and Technology Report 2021*, https://www.bmbwf.gv.at/dam/jcr:c4eae98b-17ac-4af2-92ea-340ebe9a1c72/FTB_2021_engl_bf.pdf; Austrian Federal Government (2020[50]), *RTI Strategy 2030*, https://www.bundeskanzleramt.gv.at/dam/jcr:90b413e2-ce1b-4326-9c4a-dfbb3e67d4c9/RTI_Strategy_2030.pdf; Austrian Federal Government (2020[51]), *RTI Pact 2021–2023*, https://www.bundeskanzleramt.gv.at/dam/jcr:a07cc716-1032-4ffe-a568-57d15be53c2c/RTI_Pact_2021%E2%80%932023.pdf; BMBWF and FWF (2021[52]), *Auszug Finanzierungsvereinbarung (FV) 2021–2023*, https://www.bmbwf.gv.at/dam/jcr:1e0a6c58-0299-4925-8385-b826b946fabd/FWF-FV%20barrierefrei.pdf.

5.5.3. Co-operation between policy-making bodies is limited

A number of broad and complex ("wicked") issues require resources and capabilities that go beyond the portfolio of any single ministry or agency. In this case, co-operation between different ministries and agencies pertaining to different policy fields can prove beneficial either to cover different stages of the innovation cycle (from research to deployment), different areas of competencies (for instance, support to technological development and support to skills development) and/or different thematic areas (for instance, energy and transport). Large programmes are one of the main mechanisms for collaboration among ministries and agencies across policy silos.

In Korea, since 2011, ministries have joined up on specific occasions to implement co-operative programmes. The “ministry-led inter-ministerial programmes”[38] (hereafter, “ministry-led type”) tend to be longer-term and have a larger scale and scope, and therefore subject to pre-feasibility tests (KISTEP, 2019[53]). These programmes are generally initiated bottom-up based on the demands identified by participating ministries, meaning there may be overlaps with existing programmes (KISTEP, 2019[54]). The mismatch between the operational guidelines of ministries and the limited use of inter-ministerial consultative bodies set up to promote their voluntary co-operation are other limitations of this programme type.

The government established the Multi-ministerial R&D Programme Promotion Plan in 2013 to overcome the issues affecting the ministry-led type and to facilitate a new type of joint undertaking that would be centrally managed rather than initiated by the ministries themselves. According to the plan, these joint undertakings (hereafter, the “multi-ministerial R&D programmes”) are different from the ministry-led type in that they are co-ordinated earlier in the policy cycle, from the planning stage (rather than after budget allocation to sectoral ministries) and require inter-ministerial co-operation throughout the whole programme cycle (rather than opportunistically, when needs emerge during the course of the programme). Most importantly, multi-ministerial R&D programmes are managed by the Multi-ministerial programme promotion committee (hereafter, the “Multi-ministerial Programme Committee”),[39] a permanent co-ordination structure under the PACST Deliberative Council, which reviews and selects the R&D co-operative programmes, and more generally deliberates on all issues regarding inter-ministerial co-operation. The Multi-ministerial Programme Committee is chaired by the Head of the STI Office and comprises 11 high-level government officials and 13 private experts (PACST, 2022[55]). These programmes are subject to a common set of operational guidelines, in contrast with the ministry-led type where individual regulations of sectoral ministries apply (MSIP, 2013[56]; Ministry of Legislation, 2022[57]).

The planning of multi-ministerial R&D programmes follows four steps. First, MSIT and KISTEP conduct two surveys to identify the needs for co-operation: the first is a bottom-up process in the form of calls for expression of interest to industry, academia and GRIs; and the second is a top-down process based on the demands from sectoral ministries. Second, MSIT supports the pre-selection of the candidate programmes, later to be approved by the Multi-ministerial Programme Committee. Third, once selected, the lead ministry assigned to each co-operative programme, in consultation with other ministries, develops a detailed programme plan that includes the division of labour among ministries. Finally, the developed plans are again submitted to the Multi-ministerial Programme Committee, which gives final approval (KISTEP, 2021[58]).

An example of these multi-ministerial R&D programmes is the national programme in the biomedical sector in which several ministries, such as MSIT, MOTIE, the Ministry of Health and Welfare (MOHW) and the Ministry of Food and Drug Safety (MFDS), participate. This programme aims to support the R&D and innovation activities from the ideation stage to the approval by MFDS and beyond.

While in practice, these multi-ministerial R&D programmes have a wider scale and scope in other countries, they are undertaken at the Specific Programme level in Korea (see Table 5.B.1, Annex 5.B). The number of Specific Programmes selected has been constant, at around five per year from 2013 to 2020. It recently rose to 12 in 2021. These numbers are very low compared to the overall number of Specific Programmes per year (above 1 000). These programmes are far less frequent than the ministry-led type mentioned above. In 2017, multi-ministerial R&D programmes accounted for only 10.4%, whereas the ministry-led type was 89.6% of total multi-ministerial programmes (KISTEP, 2019[53]). There is currently no formal incentive for ministries to launch multi-ministerial R&D programmes, but budget officers tend to prioritise them. An option is to reserve a dedicated central budget for these programmes in order to offer a financial "top-up" that would reduce the costs for participating ministries.

Furthermore, multi-ministerial R&D programmes often take the form of "umbrellas" to host the Internal Programmes of different ministries, managed by their own implementation agencies (see Annex Table 5.B.1..A.1, Annex 5.A) (KISTEP, 2021[59]). These programmes often replicate the vertically segmented structure between policy fields, with exclusive relationships between ministries and their respective agencies in each silo. The added value of these programmes, therefore, lies in the *ex ante* division of tasks among the participating ministries, which avoids unnecessary overlaps, and some integrated monitoring of the programme. While this undoubtedly raises the efficiency of these programmes, it falls short of more co-operative practices where integrated teams belonging to different agencies collaborate to select, manage and evaluate projects.

Different schemes exist to promote and enable this type of co-operative endeavour at the ministry or agency level in practice. In large cross-ministerial programmes, such as those in Korea, different ministries launch a common umbrella programme and delegate some components to their respective agencies. Other co-operation is implemented directly between agencies in joint programmes. These can be limited to ad hoc joint calls for proposals. They can also be more ambitious and structural, such as in cross-agency challenge-led programmes like Pilot-E in Norway, where three agencies create a one-stop-shop funding scheme to jointly fund and monitor ambitious large-scale consortia from research to deployment (see Box 5.5).

Box 5.5. An example of cross-agency STI co-operation across the innovation cycle: Pilot-E in Norway

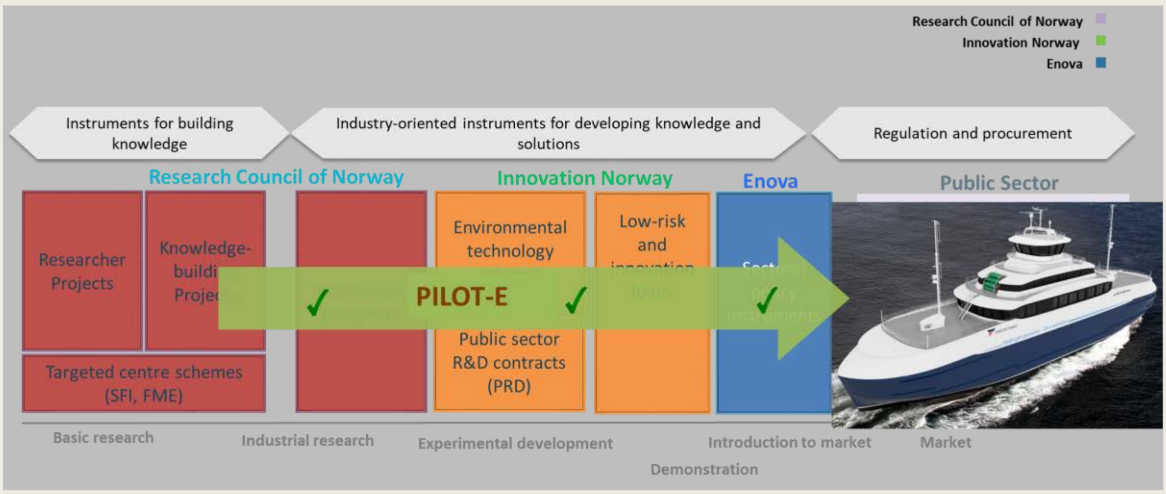
Norway has set up several cross-agency challenge-led programmes, starting in 2016 with Pilot-E. This scheme aims to be a one-stop-shop that provides seamless support from idea to market to various climate, emission-free and energy-saving solutions. Within Pilot-E, three agencies systematically co-ordinate their actions to provide tailored and seamless support to industry-led consortia along the entire pathway from research to market deployment. The scheme is governed by a dedicated structure of governance involving representatives of the three agencies. They also collectively hire and share the cost of a secretary supporting the implementation of the scheme.

Pilot-E is a joint funding instrument, gathering technology push and market pull funding instruments of the three agencies to provide comprehensive support along the innovation chain. The Research Council of Norway supports research and research-based innovation; Innovation Norway supports innovation; and Enova provides financial incentives for the uptake of new solutions among end-users, including public procurement for innovation (see Figure 5.9). Moreover, regulatory authorities are active in removing legal barriers to technology implementation.

Through joined-up action of the agencies and close monitoring of projects, Pilot-E is suited for larger consortia that address more complex challenges than traditional projects that are supported by any of the partner agencies individually. Pilot-E was positively evaluated in 2020.

This scheme is now also applied in other areas, such as transport and digitalisation (Pilot-T), health (Pilot-H) or bio-economy (Pilot-B, focusing on aquaculture and timber) areas. More recently, leveraging the Pilot-E positive experience, the Green Platform Initiative is a scheme launched in 2020 to support large-scale R&D and innovation projects that co-ordinate joint actions along the whole innovation chain from upstream research to business development, commercialisation and scaling of green transition processes, products and services. Five ministries participate in the Green Platform Initiative, which is operated by three agencies (RCN, Innovation Norway and Siva).

Figure 5.9. The funnel approach in Norway's Pilot-E: Packaging together the instruments of three agencies



Source: (Volla, 2019[60]).

Source: Larrue (2021[61]), "Mission-oriented innovation policy in Norway: Challenges, opportunities and future options", https://doi.org/10.1787/2e7c30ff-en; Larrue (2021[62]), *The design and implementation of mission-oriented innovation policies: A new systemic policy approach to address societal challenges*, https://doi.org/10.1787/3f6c76a4-en.

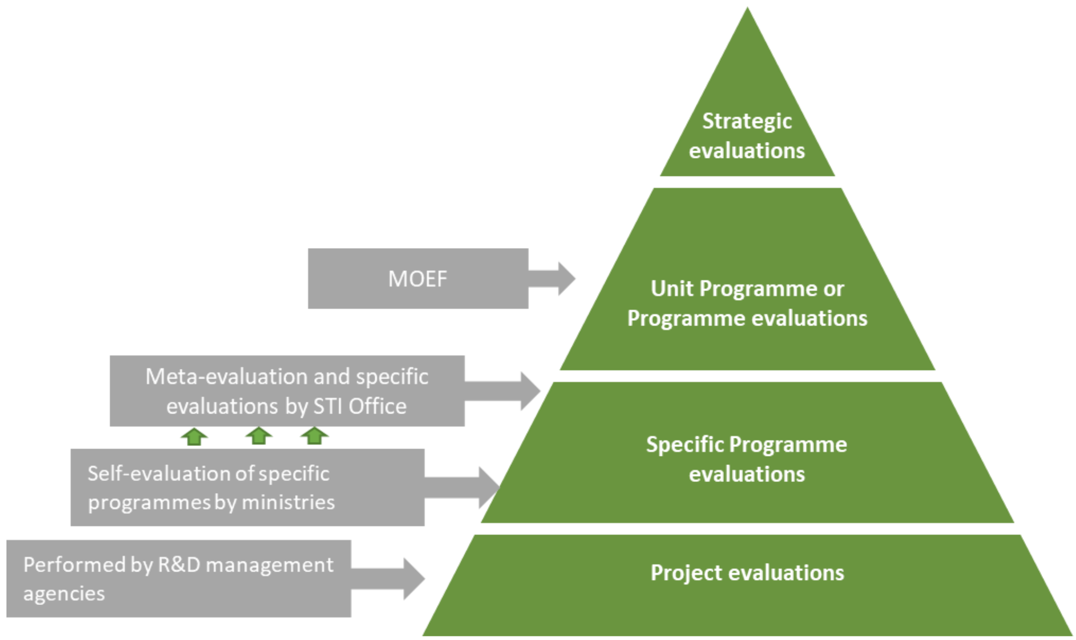
5.5.4. The monitoring and evaluation of programmes and projects has significantly changed, but it is too early to assess the impact

A system of laws, guidelines and procedures frames the monitoring and evaluation of programmes and projects. Many reforms have been enacted in the past. For instance, in 2012-13, a reform was enacted to allow for more and better reflexivity (so that, for instance, *in itinere* evaluations can lead to corrective actions, or even discontinuation, earlier in the project cycle); better structuration for greater evaluability of projects (through the strengthening of the *ex ante* review system discussed earlier); and stronger linkages between the outcomes of funded projects and future decisions regarding future programmes and projects (the results of the previous project evaluation is one of the criteria for new project proposals).

Until 2021, ministries were required to perform self-evaluations of their programmes at different stages of the programme cycle: 1) an evaluation of performance indicators (at the planning stage); 2) interim and/or specific evaluations (throughout programme implementation); 3) a final evaluation (after programme finalisation); and 4) a follow-up evaluation (within five years of programme finalisation). All these evaluations were subject to meta-evaluation by the STI Office to monitor the adequacy of the evaluation process (MSIT, 2020[63]). Ministries could be asked to reperform their self-evaluations. Furthermore, an additional step of specific evaluation was reserved for certain programmes that were longer-term, larger-scale and of high national importance, therefore requiring central co-ordination by the STI Office.[40]

In 2021, the 2005 Research Performance Evaluation Act was significantly revised. Importantly, the autonomy and responsibility of sectoral ministries for programme evaluation were strengthened, while the role of the STI Office focused on monitoring rather than evaluation. For transparency, ministries were asked to develop an evaluation strategy plan for each programme and monitor its implementation. Also, the meta-evaluation process by the STI Office was simplified (KISTEP, 2021[64]).[41] Continuing the previous reforms, another change was made to promote research quality rather than focusing solely on indicators based on the quantity of outputs. This approach helps to better capture the socio-economic impacts of research. Finally, the "follow-up evaluations" changed name to "R&D programme impact-chasing" evaluations and are now carried out by the ministries themselves. Before the reform, follow-up evaluations of Specific Programmes were performed by KISTEP.

Figure 5.10. Korea's different types of evaluation by programme



Source: Based on desk research and stakeholder interviews and OECD (2016[65]), *Evaluation Systems in Development Co-operation: 2016 Review*, https://doi.org/10.1787/9789264262065-en.

It is too early to assess the effect of such a recent reform. One can only emphasise that several reforms in the past addressing the same issues had limited effects, hence providing the rationale for a new wave of reforms. Efforts should also be dedicated to better understanding why past reforms have not yielded the expected results, including through an analysis of how the new evaluation rules and procedures are applied. Several interviewees mentioned that the issue does not lie in the formal framework, which appears to include the latest international good practices on paper (and sometimes even innovates),[42] but rather in the behaviours of actors within that framework.

5.6. Governance of the Korean sustainability transition

This section examines Korea's efforts to develop and implement cross-cutting strategic and policy frameworks to support its transition to a more sustainable model and, in particular, achieve its commitment to a net-zero economy.

5.6.1. Orienting funding towards addressing societal challenges

Korea has demonstrated a growing awareness of the importance and urgency of societal challenges and started reforming its governance and policy framework accordingly. In 2013, MSIT prepared the first Comprehensive Plan on S&T-based solutions for social problems[43] as an inter-ministerial plan. In 2018, the second Comprehensive Plan aimed to improve living standards through STI. It included three main strategic thrusts aiming to: 1) build an inter-ministerial co-operation structure to invest public R&D in areas of public demand; 2) form an ecosystem for social problem-solving R&D; and 3) strengthen the social contribution of STI. To that end, the Comprehensive Plan identified 41 society-related problems in 10 fields.[44] Also in 2018, as mandated by the plan, the first public-private consultative meeting was formed, including with high-level government officials (both central and local) and private experts (firms, academia and GRIs). Such meetings are organised each quarter of the year by the Head of the STI Office.

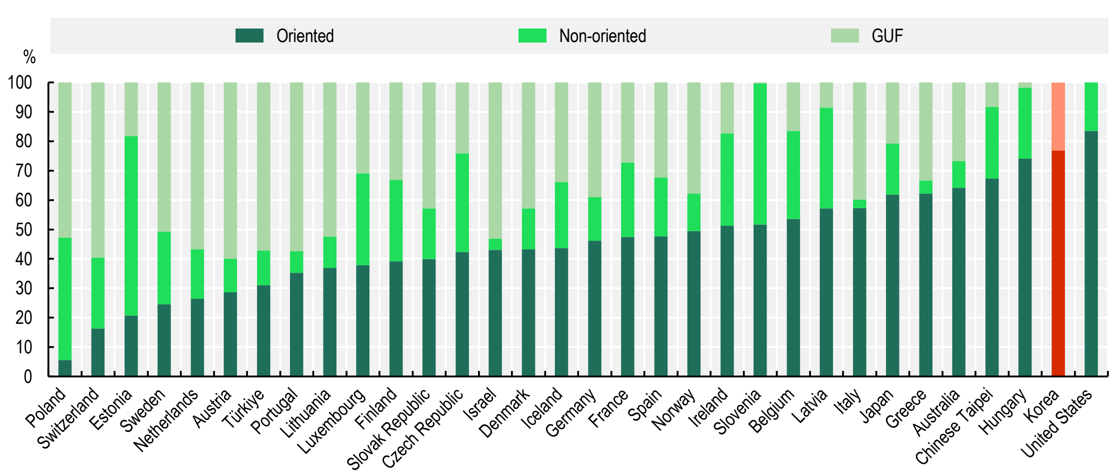
Furthermore, in 2021, MSIT developed the Social Problem-solving R&D Guidelines for ministries in order to increase the contribution of R&D to public well-being (MSIT, 2021[66]). The guidelines define the three core features of such programmes: establishing objectives that reflect high social demands; being supported by a governance structure that includes relevant stakeholders; and generating increased impact in response to identified problems. The guidelines are intended to be used by ministries across the programme cycle of their R&D programmes, from planning and budgeting to performance management.

International experience suggests that there is often a comprehensive gap between plans and concrete actions when it comes to societal challenges. One way to assess whether Korea has moved beyond intentions is to try to analyse funding trends of "social problem-solving" R&D. A first element to consider is the capacity of the government to allocate funding to specific issues (i.e. oriented or "directional" funding), thus not only providing neutral support, e.g. through an R&D tax credit.

A large portion of Korea's government appropriations dedicated to R&D is thematically oriented (Figure 5.11). Non-oriented research includes both research for the general advancement of knowledge and institutional funding. Oriented research includes research reported by national authorities as contributing to specific socio-economic objectives. In Korea, public funds for oriented research accounted for 75% of the total (direct) fund for R&D in 2020 (85% in the United States, 68% in Japan, and 46% in Germany). The general university fund (GUF), which mainly includes institutional funding to universities, is null in Korea since institutional funding of universities only covers the educational mission of universities (see Chapter 4).

Figure 5.11. Oriented and non-oriented government budget allocations for R&D (GBARD) in Korea and selected economies, 2021

As a percentage of civil GBARD

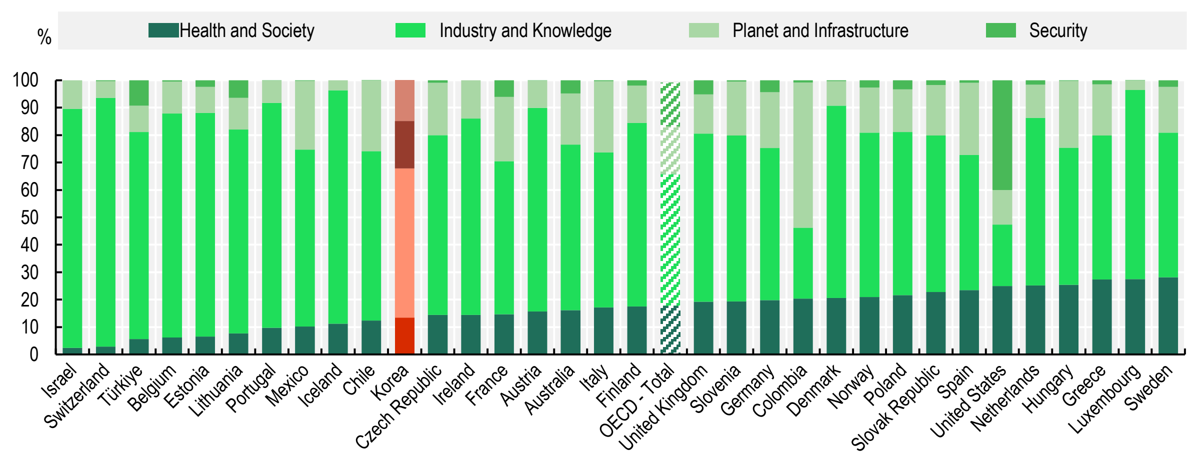


Note: Non-oriented research for Korea includes GUF. Differences in methodology for Australia, Austria, Israel and Japan. Estimated values for Denmark, France and Sweden.
Source: Authors' calculations based on OECD (2021[67]), "Research and Development Statistics: Government budget appropriations or outlays for R&D", https://doi.org/10.1787/620bbce8-en (accessed on 20 June 2023).

The allocation of public funds for R&D in Korea reveals that the country dedicates a relatively small proportion of its government R&D budget to projects and activities related to health and society issues. In 2019, only 14% of R&D funds were allocated to these areas, compared to 32% in Sweden and 21% in Germany (Figure 5.12). As in most countries, it is experiencing an upward trend (it was 9% in 2012). A higher share in international comparison is allocated to security-related R&D (15%, second to the United States in Figure 5.12. As in almost all countries, most of Korea's R&D resources are directed towards industry and knowledge (53%).

Figure 5.12. Government R&D budgets by Sustainable Development Goal-related category, Korea and selected OECD countries, 2020 or latest available

As a percentage of total GBARD



Note: Data for Chile, Germany, Iceland, Spain and the United States correspond to 2019.
Source: OECD, Research and Development Statistics Database, http://oe.cd/rds (accessed on 21 June 2023).

According to research by KISTEP, the share of the Korean R&D budget dedicated to societal issues is rising (a 10% increase in 2021) but remains low, representing only 5.8% of the total R&D budget (KISTEP, 2021[68]). The main contributors to this budget were MSIT, the Ministry of Welfare and MOTIE.

For example, in the energy sector, which accounts for most of the greenhouse gas (GHG) emissions in Korea, funding for fossil fuel research, development and demonstration (RD&D) (and nuclear RD&D) significantly decreased between 2013 and 2019. However, funding for renewable energy, hydrogen and fuel cells, and other power and storage technologies has not significantly increased or at all.

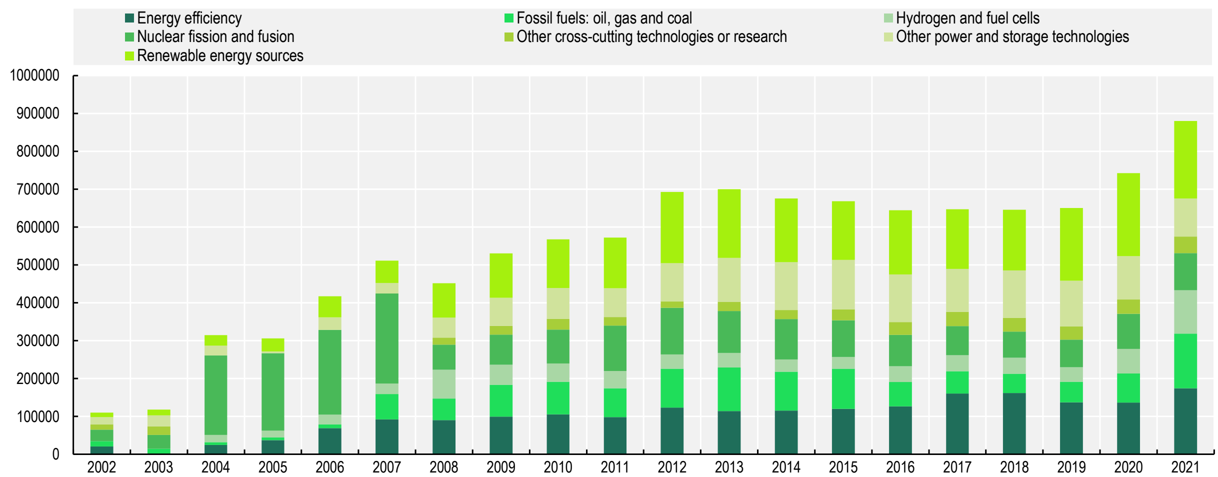
As a result of the Green New Deal (see below), Korean energy RD&D increased significantly in 2020 and even more so in 2021 (see Figure 5.13). However, despite this increase, Korea ranked 8th in terms of RD&D budgets dedicated to energy among International Energy Agency (IEA) member countries in 2021 and 13th when normalised by level of gross domestic product (GDP).[45] The Korean energy RD&D budget (EUR 659 million) was about half of Germany's (EUR 1 354 million) in 2021, which is consistent with their GDP difference. However, German public investment in energy RD&D has increased far more steadily since the beginning of the 2000s (with a drastic increase in 2022 due to the national Recovery and Resilience Plan) than Korea's.

The allocation of the energy RD&D budget among the different technologies is also enlightening. While Korea invests mainly in renewables (23%) and energy efficiency (20%), Germany focuses on hydrogen and fuel cell technologies (29%) and renewables (16%). Korea still invests a significant share of its energy

RD&D budget in fossil fuels technologies (16%), compared with less than 2% in Germany, 3% in France and 5% in Japan despite their large automobile industries (IEA, 2022[69]).

Figure 5.13. Korea's energy RD&D budget by technology, 2002-21

In KRW millions (2019 prices)



Source: IEA (2022[69]), *Energy Technology RD&D Budgets* (database), https://www.iea.org/reports/energy-technology-rdd-budgets-overview/data-explorer#abstract (accessed on 21 July 2022).

5.6.2. Governance of the net-zero agenda remains fragmented

As shown in Chapter 2, Korea is one of the few advanced countries where GHG emissions continue to rise, and the national CO_2 intensity of GDP remains one of the highest among OECD countries (see Chapter 2, Figure 2.28, Panel B). Korea's GHG emission intensity per capita is still above the OECD average (third-highest intensity after Canada and Australia) and has increased since 2000. The power sector is the main source of emissions, and its emissions have increased by 42% since 2008 (an increase of 21% in the transport sector and other energy sectors by 23%) (IEA, 2020[70]).

However, achieving net-zero commitments is a considerable challenge for all countries regardless of their recent results in terms of emission mitigation. In response to this imperative, countries are implementing an increasing range of STI policy experiments to support their sustainability transitions. A growing body of literature in environmental and science policy studies exists to guide and learn from these experiments. Although there is still much uncertainty regarding the most effective types of design to address ambitious societal challenges, including climate change and rapid ageing, and bring about needed systemic change, a consensus prevails on some overall principles.

The urgency, complexity and systemic scope of the most pressing societal challenges call for proactive policies where the state has a strong role to play in initiating and steering relevant initiatives. The needed government intervention goes far beyond issuing a list of national priorities or key technologies or even developing an overall STI strategy or plan. Public authorities play the role of orchestrators of large strategic and policy frameworks dedicated to solving specific challenges or objectives, with the strong involvement of a wide range of policy actors and other public and private stakeholders.

The cross-cutting and systemic nature of the societal challenges requires an unprecedented level of holistic co-ordination of a wide-ranging policy mix. In order to reduce GHG emissions, for instance, supporting the R&D of novel solutions cannot be disconnected from the skills needed to produce and maintain these technologies, the new needed infrastructure, the supply of new materials, the regulatory changes required to experiment and diffuse the technologies or even the behavioural and social changes associated with the use of the new technologies. The electric vehicle illustrates this point. Even more, these efforts should also be linked to the activities on many other complementary or competing technologies that will be necessary to trigger the necessary system transition, often belonging to different industries and based on different scientific disciplines and bodies of knowledge. In short, societal challenges that are systemic in nature require system innovations, which calls for systemic policies (OECD, 2015[71]).

In Korea, following the President's commitment to combat climate change, the government proposed in October 2020 to achieve carbon neutrality by 2050. The Framework Act on Carbon Neutrality and Green Growth for Climate Change[46] entered into force in 2022. It includes a goal to cut GHG emissions by 40% by 2030 (compared to 2018) and reach net-zero emissions by 2050. This Act demonstrates that Korean society at large is now firmly committed to achieving the sustainability transition and is ready to engage in bold actions, such as replacing fossil fuel power generation with renewable energy and green hydrogen, using carbon capture, usage and storage (CCUS) technology and, for instance, shifting towards zero-emission vehicles. This evolution is recent and remains to be confirmed in years to come, as difficult trade-offs, with potentially significant economic and social consequences, will have to be made. The challenge is considerable, given Korea's high level of emissions.

The government has launched comprehensive policy plans and programmes to implement these commitments. As already mentioned, the 2050 Carbon Neutrality and Green Growth Commission is a specific body established in May 2021 to serve as the "control tower" of all carbon neutrality policies in the country (the Net-Zero Policy framework) and as a platform for citizen consultation and engagement (2050 Carbon Neutrality and Green Growth Commission, 2022[72]). The commission is headed by the Prime Minister and has four sub-committees composed of public and private stakeholders.[47] In 2021, the commission released two policy roadmaps for carbon neutrality (corresponding to two scenarios)[48] and is mandated to approve and monitor Korea's net-zero policy agenda.

The National Green Growth Strategy for Carbon Neutrality was launched in October 2022. It includes four main policy orientations: 1) responsible carbon neutrality through concrete and efficient solutions; 2) innovative carbon neutrality and green growth led by the private sector; 3) carbon neutrality led by the co-operation of all members of society; and active participation to carbon neutrality leading the global market and the international community. Based on these four orientations, twelve key projects were defined, and specific policy directions and responsible departments were specified. Furthermore, the Commission also launched the Strategy for Green Growth Technology Innovation during the same period. It includes three main orientations: technological innovation toward carbon neutrality mainly through private-sector-led missions; enhanced investment in rapid and flexible carbon-neutral R&D; and pre-emptive building of infrastructure for innovative technology development. With innovation being an important factor in the achievement of these strategies and roadmaps,[49] it is important to ensure a formal connection between PACST and the Net Zero and Green Growth Commission.

One option would be that all committees with significant prerogatives in reducing GHG emissions meet in a specific format about twice a year, possibly with a dedicated monitoring report.

5.6.3. An ambitious yet traditional policy framework for the transition to net-zero

One of the components of the policy framework is the Korean New Deal. This overarching plan was announced in April 2020 as a new stimulus package to lessen the impact of the COVID-19 crisis and pave the way towards the "post-coronavirus era". Geared to support the "twin transitions", it was composed of two main pillars, the Digital New Deal (DND) and the Green New Deal (GND). The Safety Net programme complemented these two pillars. In 2021, the GND budget was KRW 8.1 trillion, mainly focused on infrastructure, energy supply and industry (Government of Korea, 2021[73]). It set precise targets to be achieved at key milestones, including the overarching goal of creating 1 901 000 jobs by 2025.[50] The initiative is structured along nine policy areas (four on DND, three on GND and two on the Safety Net component) and ten "major tasks".

In 2021, upon reassessing the recent changes in both domestic and external environments and their impact on Korean society, the government rebranded the initiative to Korean New Deal 2.0 (hereafter, "KND 2.0"). While the timeline (2020-25) has remained unchanged, the national budget increased from KRW 160 trillion to KRW 220 trillion to create 2.5 million jobs (compared to 1.9 million) (Government of Korea, 2021[74]). The biggest change is that the social safety net measures that were previously regarded as foundational, but rather supplementary policies, to facilitate the digital and green transition under the pillars of DND and GND were regrouped into the "Human New Deal" (HND) programme. KND 2.0 is, therefore, now composed of three programmes (DND, GND and HND). The policy areas were redefined and expanded from 9 to 12. Furthermore, an additional programme, the Regional Balance New Deal, is planned with a dedicated budget to help regions – particularly the least developed ones – benefit from KND 2.0. For instance, some funds will be used to incentivise local governments that participate in KND 2.0 projects. There are also plans to reduce the bureaucratic burden (including the feasibility tests) to launch new green development projects in local areas.

Dedicated governance structures are set to co-ordinate and monitor the overarching plan and its three components. At the highest level is the Strategy Meeting on the Korean New Deal convened by the President. This meeting is supported by the Government-Party Headquarters for the Korean New Deal (hereafter, "HQ"). The HQ is headed jointly by the Minister of Economy and Finance (Vice Prime Minister) and the General Manager of the Office of KND within the major political party. The members, by design, include both ministers of MSIT, MOE, MOTIE and the Ministry of Employment and Labour (MOEL),[51] representing the government and leading the three components of KND, and the corresponding three heads of divisions from the political party (Korean New Deal, 2022[75]).

The fiscal investment in GND planned until 2025 is KRW 97 trillion, of which KRW 61 trillion comes from the national budget. In 2022, KRW 13.3 trillion of government investment is planned, which is the largest sum of all three pillars (Government of Korea, 2021[74]). The four tasks defined are: 1) building policy for carbon neutrality (newly introduced under KND 2.0); 2) exploring green transition options for city infrastructures and lifestyle; 3) diffusion of low-carbon energy sources; and 4) establishing an innovative ecosystem for green industries.

While the budgets and scope of these new initiatives are considerable, it is unclear whether they represent a qualitative shift from traditional strategy and modes of intervention. It appears to focus more on inputs – allocating money into the system – than impact. It is essentially an umbrella for ten large programmes with rather short-term objectives, implemented by different ministries. Furthermore, the GND's prime objective seems to concentrate on achieving economic recovery through new green business activities.

Since starting from an umbrella recovery programme in 2010, France has continuously strengthened the integration of its Investments for the Future programme (PIA). The latest edition, launched in 2021, includes a "directed logic" component, where large and ambitious challenges are tackled through inter-ministerial Acceleration Strategies (see Box 5.6).

Box 5.6. France's STI framework to support its sustainability transition

The French government launched the Investments for the Future programme (PIA) in 2010 to promote investments and innovation in key sectors to stimulate employment, boost productivity and increase the competitiveness of French businesses. The PIA is characterised by centralised inter-ministerial steering led by the General Secretariat for Investment (SGPI), which, under the authority of the Prime Minister, is responsible for ensuring the general consistency and monitoring of the state's investment in PIA. PIA's implementation is decentralised in funding agencies.

Three PIAs have been launched since PIA1 in 2010 (PIA2 in 2013, PIA3 in 2017 and PIA4 in 2021, covering 2021-25) with an overall investment of about EUR 67 billion. Priorities have evolved with each new PIA, with a growing focus on R&I activities that can contribute to the ecological transition. PIA4 has set a target of at least one-third of investments supporting the ecological transition. The evaluation of the first ten years of PIA (i.e. covering PIA1 and PIA2) in 2019 highlighted a need to renew the original PIA strategic investment priorities and streamline the intervention tools to better integrate the support for R&I in the upstream and downstream phases and be more impactful.

PIA4 (integrated into France Relance 2030 since 2022), launched in 2021, responds to this call for a renewal of the programme. It has a EUR 20 billion budget and is structured in two main "intervention logics". The "structural logic" provides long-term sustainable funding to key R&I institutions. The "directed logic" promotes a more directional approach to support exceptional investments to meet five "grand challenges": 1) securing, certification and reliability of AI; 2) improving medical diagnostics through AI; 3) cybersecurity – making France's systems sustainable and resilient to cyber-attacks; 4) producing high value-added proteins biologically and at a reduced cost; 5) development of high-density energy storage for sustainable mobility. These challenges were selected by the Innovation Council, which was created in 2018 to define the main priority orientations of French innovation policy, define cross-cutting actions and simplify the French R&I policy landscape.

The main instruments of the "directed logic" component are the Acceleration Strategies. In specific challenge areas, these large initiatives aim to identify the main socio-economic transition challenges and to invest in tackling these challenges using a global and systemic approach combining various modes of intervention (research, training, financing, standards and norms, taxation, etc.). The expected added value of Acceleration Strategies is not primarily in the novelty of the supported activities but in their stronger strategic steering and integration across the entire innovation cycle. While the objectives of the first PIA were politically determined in 2010 in the context of the 2008 financial crisis, the PIA4's Acceleration Strategies are co-constructed by all relevant partners.

The Carbon-free Hydrogen Acceleration Strategy has set targets for 2030, including the installation of a carbon-free hydrogen production capacity of 6.5 GW (gigawatt) by electrolysis, the saving of more than 6 Mt (metric tonnes) of CO_2 and the creation of 50 000-150 000 direct and indirect jobs in France. Each strategy has its own governance structure, with a dedicated inter-ministerial co-ordinator who reports to the Innovation Council. The task of the co-ordinator is to lead the inter-ministerial co-ordination and monitoring of all the actions implemented. The Carbon-free Hydrogen Acceleration Strategy has a budget of EUR 3.4 billion during the period 2020-23, and EUR 7 billion is planned until 2030. The strategy covers all aspects related to establishing a hydrogen value chain (*filière*) from research to production, pipelines, skills and markets. The strategy also aims to develop key technologies and components through pilot projects for different types of usages and markets.

One essential added value of each Acceleration Strategy is integrating all instruments, from exploratory research programmes to price-based mechanisms, in a common institutional space with a dedicated governance structure gathering various ministries and stakeholders.

Source: Various sources, notably the SGPI website, https://www.gouvernement.fr/secretariat-general-pour-l-investissement-sgpi.

5.6.4. Korea has launched mission-oriented policy experiments, but these remain too narrowly focused on technologies

The OECD defines mission-oriented innovation policies (MOIPs) as a co-ordinated package of policy and regulatory measures tailored specifically to mobilise STI in order to address well-defined objectives related to a societal challenge in a defined timeframe. These measures possibly span different stages of the innovation cycle from research to demonstration and market deployment, mix supply-push and demand-pull instruments, and cut across various policy fields, sectors and disciplines (Larrue, 2021[62]). The specificity of this approach is to integrate into the same institutional space the three key functions of an innovation system as presented earlier: 1) strategic orientation; 2) co-ordination/programming; and 3) policy implementation. Mission-oriented policies are therefore not limited to a strategy, a cross-ministerial committee or a new plan including various policy measures but integrate these three elements. A mission-oriented policy should include: 1) concrete objectives to be achieved linked to a challenge to be met; 2) a dedicated governance structure (inter-ministerial, possibly multi-level, with public and private actors); 3) a tailor-made policy mix (including financial tools to encourage research and support demand; qualitative support measures, regulations, etc.) to achieve goals; and 4) a "reserved" budget.

Korea has demonstrated a strong interest in MOIPs in the last three to four years. It has launched two main initiatives to pursue ambitious goals, with projects financed for up to nine years. They pertain to the challenge-led schemes designed after the US Defense Advanced Research Projects Agency (DARPA) model. These can be effective in accelerating technical changes in some targeted areas but fall short of supporting more systemic innovation that links technological, behavioural, regulatory, social and market innovation. Other countries, such as Germany, Japan and the Netherlands, have set up broad systemic frameworks to realise long-term "national missions". The characteristics of the Korean programmes are consistent with their main objective, which is to strengthen national competitiveness. The mobilisation of this policy approach to support the green transition will require a different type of design and governance. Some recent announcements propose to follow this route but have not yet been enacted.

Korea implements "DARPA-like" challenge-led schemes

There are two main types of MOIPs:

1. **Overarching mission-oriented policy frameworks** aim to realise wide and ambitious national missions (e.g. reducing GHG emissions, fighting cancer). They are systemic in nature and link various types of alternative or complementary solutions (mixing technological, social, behavioural and regulatory changes). For instance, Germany set 12 national missions in its High-Tech Strategy 2025; Japan has 9 Moonshot Goals; and the Netherlands has 25 missions as part of its Mission-driven Top Sectors Policy.
2. **Challenge-led schemes** are focused on a narrower objective (e.g. developing green ships or a system for automatic textile recycling). These are often of a more scientific or technological nature and put the emphasis on R&D activities. To various degrees, these initiatives emulate some of the characteristics of the high-risk, high-reward model implemented by the United States (DARPA).

In the last three to four years, Korea has demonstrated a strong interest in MOIPs, actively engaging in the work of OECD on this policy approach and experimenting with different schemes, all pertaining to the Type 2 presented above. The National Plan for Strengthening Innovative and Challenge-led R&D[52] was adopted in 2019 to prepare the foundation for "mission-oriented problem-solving R&D" programmes.

Currently, three types of national programmes fall under the wide definition of challenge-led missions in Korea:

- the Korea Advanced Research Programme (KARPA) by MSIT
- the Alchemist by MOTIE
- the Future Challenge Technology Development Programme by the Ministry of Defence.[53]

KARPA was created under the leadership of MSIT in 2020 to run from 2020 to 2024.[54] It aims to, first, generate innovative outcomes that can bring about socio-economic transformations and, second, to encourage more ambitious and efficient research. KARPA establishes three research areas (i.e. happy and healthy ageing; safe and pleasant society; sustainable growth of Korea's economy) and five criteria (i.e. clarity, challenge-orientation, innovativeness, originality, impact) based on which "research themes" are selected. The research themes fall into two types. First, the "exploratory" type funds projects for about four years from ideation until the proof-of-concept phase (therefore, short term). Second, the "package" type funds the whole cycle from R&D to demonstration phases for a maximum of nine years (longer term). The appointed KARPA director selects five themes annually in consultation with the Innovative and Challenge-led Project Programme Committee (see below) and develops detailed plans for some of them, to be implemented by ministries and their agencies.[55] The annual budget for KARPA operation was around KRW 1.4-1.8 billion for 2020-22. While each ministry has to follow the normal budget request process for their KARPA programmes, the STI Office recognises the specificity of these programmes. They are, therefore, treated with more attention and flexibility to adapt to their specificities.

A specific regulation, the Operation and Management Regulation for Innovative and Challenge-led Projects, provides the legal basis for KARPA. Within this programme, private programme directors manage cross-ministerial national projects with an aim to generate a large social and economic impact despite the risk of failure (Ministry of Legislation, 2020[76]). A private-public joint committee including 12 ministries, the Innovative and Challenge-led Project Programme Committee, was established under MSIT to review the plans developed by the programme directors and take charge of the inter-ministerial co-ordination.

The Alchemist is a high-risk, high-reward R&D programme owned by MOTIE. The programme aims to promote disruptive and breakthrough technologies for future generations with the help of R&D. It also seeks to tackle some of the weaknesses of the Korean R&D system, in particular, relatively low performance compared to large and annually growing R&D investment (input-oriented) and a low appetite for conceptually new and risky projects. MOTIE launched the programme in 2019 with the Korea Evaluation Institute of Industrial Technology (KEIT). The pilot programme ran from 2019 to 2021; in 2021, the programme passed the pre-feasibility test with a budget of KRW 414.2 billion earmarked for 2022-27 (of which KRW 374.2 billion comes from the national budget and the rest from the private sector). The Alchemist programme adopts a stage-gate and competition approach, where six projects are selected for the concept phase (funded for one year), three for the pilot phase (one year) and one for the main research phase (five years).

The government has ambitious plans for the future of mission-oriented policies in Korea

The government has identified inefficiencies in the current governance and budgeting of the Korean STI system that hamper cross-ministerial challenge-led R&D programmes (MSIT/STEPI, 2021[77]) (MSIT/STEPI, 2021[77]). The areas for improvement identified by this exercise included: 1) lack of co-ordination between ministries, which hinders a clear identification of their respective roles in implementing such programmes; 2) insufficient scale of the budgets for these programmes, defined within the budget ceilings set by MOEF, which tend to demotivate ministries' participation (according to the results of this exercise); 3) time needed (on average, two to three years) to reflect for the budgets of these programmes in the respective ministries' budget portfolios, which compromises their timely implementation.

In order to overcome these problems, the government foresees a two-step – short-term and mid- to long-term – promotion plan to set up a sound institutional setting for the challenge-led scheme. The short-term reform plan (until 2024) involves establishing cross-ministerial government and R&D regulations more conducive to implementing challenge-led R&D programmes. This includes a dedicated budget, a revision of the pre-feasibility test regulation and changes to the management and leadership of these programmes. On a longer-term horizon (from 2025 onwards), a bill submitted to the parliament contains a clause that stipulates that the government can designate organisations for planning, evaluation and management of challenge-led missions.

So far, Korea has mainly implemented 'challenge-led missions' as defined previously. However, there has been an increasing interest in 'overarching mission-oriented policy frameworks' in recent years, which has led to new policy developments. This could have important positive impacts since this policy approach provides a crucial complement to the more focused type in that it can bring about more systemic changes necessary for sustainability transitions to succeed. According to Kuttinen, Polt and Weber's (2019[78]) mission typology, challenge-based mission schemes can achieve "acceleration missions", whereas broader national mission frameworks, such as the Danish Green Missions, as well as the German High-Tech Strategy 2025 and the Dutch Mission-Driven Top Sectors, are considered transformative missions (Kuttinen, Polt and Weber, 2019[78]).

Box 5.7. An example of national missions: Innovation Fund Denmark's Green Missions

The objective of Innovation Fund Denmark's Green Missions is to make a significant contribution to the green transformation of society and the development of sustainable climate technologies. Concretely, the missions should contribute to the country's net-zero commitments. Four missions have been launched: 1) capture and storage or use of CO_2; 2) green fuels for transport and industry (Power-to-X, etc.); 3) climate- and environment-friendly agriculture and food production; and 4) recycling and reduction of plastic waste.

Each mission has its own overarching objectives and specific objectives. For instance, the green fuels mission aims, among others, to harness the potential to capture, store or use to the order of 4-9 million tonnes of Danish CO_2 emissions.

The missions were selected according to the following criteria: the green potential of the area (to contribute to net-zero objectives); national professional strength (of the Danish business community); potential (of the market of the related green solutions); research strengths (expertise of Danish researchers and ability to enter into international collaborations and partnerships); and partnership potential (scope to support R&I partnerships where there is a clear basis for co-operation between universities, companies, public authorities, etc.).

In the agreement on the Research Reserve 2021, a total of DKK 700 million (Danish krone) (approximately EUR 94 million) was set aside to establish Green Research and Innovation Partnerships that meet specific missions. Each mission has a dedicated minimum budget.

The missions are implemented through the Innovation Fund Denmark in two stages.

1. Call for roadmaps. All relevant stakeholders across the Danish R&I system are encouraged to come together to contribute their expertise and propose a realistic and robust path toward developing or accelerating cutting-edge solutions to achieve the mission's objectives. The roadmaps need to describe challenges and gaps within the mission, strongholds and potential and sketch key activities and relevant workstream themes for future partnerships. Roadmaps are expected to cover the entire value chain and collect all driving forces from all types of organisations (from researchers to investors, education and talent, legislators, authorities, users, etc.) and include descriptions of technical, implementation/regulatory, and business/financial pathways to the vision. They should outline how it will range from strategic research to commercialisation, with a focus on short-, mid- and long-term impact. All types of stakeholders can put forward a roadmap.
2. Call for partnerships to implement selected roadmaps. Selected roadmaps proceed to the partnership phase. This decision is based on an evaluation undertaken by the Innovation Fund Denmark's Board. The overall call process is identical across the missions, but each mission can be treated differently in terms of the number of partnerships, structure and level of ambition according to the maturity and key challenges in each mission.

   Investments in partnerships are split into two steps. The first step focuses on the foundation of the partnership, including management, governance, capacity building, infrastructure, communications, relations and the primary research work streams (activities within the first year). The second step describes specific R&D activities and efforts aligned with the overall vision and goals of the partnership. There is the expectation that the broad, strong and agile partnerships comprise the whole value chain, a short- or mid-term result focus, a five-year partnership period, and a partnership centred around fulfilling the mission goals.

There is a two-step process for selecting partnerships. First, there is an initial assessment of the proposal. Second, there is an interview with a panel of national and/or international experts and possibly board members and other relevant stakeholders. Finally, there is a request for an investment proposal, on which a decision to move forward is made.

The partnerships are structured as a consortium. Governance of the partnership entails a General Assembly, a Partnership Board of Directors, and a project management group, including five scientific leads and project leads, and the project management group, are aided by a secretariat. These bodies get inspiration from an international advisory board and a national stakeholder sounding board.

Source: OECD.

PACST made recommendations in 2020 to set up national missions with clear and ambitious goals related to societal challenges (PACST, 2021[79]). According to the draft plan, the STI Office must designate a lead ministry and agency to take charge of the national missions. The ministry would set a specific but ambitious goal within a defined timeframe, which would have to include the R&D roadmap, later to be submitted to and approved by PACST. In order to monitor the implementation process, the R&D monitoring committees would be established under PACST for each challenge. They would bring together different relevant ministries, experts (industry, academia, GRIs) and the public.

While these recommendations were not taken on board as such, the Deliberative Council R&D Budget Allocation and Co-ordination Plan for 2023 (see Figure 5.7) took up the issue of mission-oriented policies (PACST, 2022[80]). It pledges to strengthen investments in mission-oriented R&D[56] to solve socio-economic challenges that necessitate whole-of-government interventions. Examples of these missions include climate change and securing national strategic technologies. In particular, they proposed to set up a specific funding framework for national missions that aim to solve societal problems (PACST, 2022[80]). Within these missions, the funding across the whole innovation cycle would be integrated, from basic research to market deployment. This could represent a significant way forward to reduce the fragmentation of the policy mix. However, no information is yet provided on how this integration will be achieved in practice.

More generally, the plan proposes to experiment with more strategic and integrated platform-based funding between ministries to fund R&I initiatives dealing with societal challenges. The investment priorities would be reviewed by the existing expert committees under the Management Committee of the PACST Deliberative Council. The soon-to-be-established National Centre for Technology Strategy (NCTS) could support the STI Office by analysing the portfolio and strategic investment of the relevant areas.

These options are still at an early stage, and little information was available at the time of writing. Despite governance arrangements, the funding of the missions is particularly crucial. As previously mentioned, the fierce competition between ministries for budgets limits co-operation opportunities in Korea. Against this backdrop, whether missions will be financed – at least partly – by some specific, centrally operated fund will be crucial to incentivising joint endeavours. In the absence of such “budget top-ups” for ministries contributing to missions, the same barriers that hinder large-scale cross-ministerial programmes will also affect the missions.

To respond to the growing need for a mission-oriented policy framework, PACST approved MSIT’s mission-oriented policy strategy in October 2022. (PACST, 2022[81]). The strategy calls for “solving national socio-economic challenges through mission-oriented R&D innovation" and identifies eight projects to be implemented in three areas: R&D investment based on clear missions; strategic investment to overcome fiscal limitations; and innovative and flexible R&D implementation. The framework will be first implemented in two major areas where S&T can bring about significant changes and produce tangible results: carbon neutrality by 2050 and fostering national strategic technologies. Based on the expected outcome, the scope of the mission-oriented R&D will be expanded to other areas, such as ageing society and epidemics.

The mission-oriented approach will consist of three main components:

1. First, the government will focus on establishing necessary roadmaps and leading bodies in order to implement effective mission-oriented R&D. Furthermore, a public-private council in five technology areas will be created in order to actively collect opinions from private actors. The five areas include: carbon neutrality; renewable energy; future biotechnology; future mobility; and digital transition.
2. Second, the current rigidity in budget allocation will be reduced so projects can adapt quickly to changes in technology and the environment. The pre-feasibility test process will be shortened and reformed where necessary to secure the timeliness of mission-oriented R&D projects. Furthermore, various funding allocation processes will be promoted as needed.
3. Third, the accountability and flexibility of project management will be improved for mission-oriented R&D projects. A project manager with powerful authority will be appointed. The projects will be permitted to change their mission and goals to adapt to the changing environment. Lastly, the mission-oriented R&D project will be closely monitored at each step and evaluated based on clear and specific performance indicators.

5.7. Synthesis

Table 5.4 sets out the main achievements and challenges of the Korean STI governance system.

Table 5.4. Korea's main achievements and challenges related to its STI governance system

Achievements	Challenges
Strategic orientation • Korea's strong foresight system systematically informs whole-of-government and sectoral strategies and plans. • Korea has a comprehensive framework to link the long-term, mid-term and annual plans across the government structure.	Strategic orientation • There is a potential disruption in the long-term strategy due to the presidential cycle in Korea. • Despite progress in Korea's 6th Foresight exercise, foresight remains too technology-focused and expert-based and falls short of more systemic and inclusive foresight exercises.
Co-ordination and programming • Korea has a central STI co-ordination unit ("control tower") with a powerful mandate to co-ordinate STI-related budgets, plans and activities of more than 20 ministries that intervene in this area. • There is a systematic reduction of programme overlaps between ministries, allowing for significant efficiency gains in Korea.	Co-ordination and programming • Despite a unique governance structure, cross-ministerial co-ordination is still considered a significant issue in the Korean STI system, according to surveys and interviews. • Emphasis of central organisations on annual monitoring of sectoral ministries' compliance happens to the detriment of higher-level and more holistic co-ordination.
Policy implementation • Korea is implementing reforms to improve agencies' activities and provide more autonomy to research organisations. • There is growing interest in mission-oriented policies and the implementation of two DARPA-type challenge-led schemes in Korea.	Policy implementation • Cross-ministerial and cross-agency co-operation often perform as large umbrella programmes in Korea and are limited in number. • Governance of agencies by their "principal" is not sufficiently linked to their plans and performance in Korea. • Korea's mission-oriented policies remain confined to technological and engineering projects with limited systemic scope.

Annex 5.A. Korea's main centralised governance arrangements and associated processes

Annex Table 5.A.1. Korea's main centralised governance arrangements and associated processes

	Governance arrangements	Associated processes	Objectives
1. Strategic orientation	**S&T long-term vision** Latest: Innovate KOREA 2045, launched in 2020	• Developed by the STI Office, in consultation with other ministries • Validated by PACST Deliberative Council	• Provide long-term guidelines for S&T mid-term strategies and plans • Lay out the long-term desired orientations for Korean society and S&T challenges to be tackled
	Five-year Basic S&T Plan Latest: Basic Plan 2018-22; in preparation Basic Plan 2023-27	• Developed by an ad hoc planning committee (and several sectoral sub-committees and working groups) under the STI Office • Ministries and various actors consulted on draft versions • Process orchestrated and co-ordinated by the STI Office • Validated by PACST Deliberative Council	• Provide the orientations for the whole STI innovation system • Most authoritative STI strategic document. By law (Framework Act), the Basic Plan must be implemented by all ministries with relevant activities and local governments
	Ministries' S&T mid- to long-term plans About 90 plans. Example: National Strategy for Artificial Intelligence (2019-30)	• Developed by sectoral ministries • Reviewed by STI Office (consistency check) • Validated by PACST Deliberative Council	• Set the mid- to long-term STI orientations of all ministries in line with the S&T Basic Plan
	Five-Year S&T Investment Plan	• Developed by the STI Office, in consultation with other ministries	• Provide the orientations for the R&D investment for the implementation of the S&T Basic Plan • Will include budget figures
2. Co-ordination and programming	**Ministries' S&T annual action plans** About 80-90 plans	• Developed by sectoral ministries • Reviewed by the STI Office to avoid unnecessary overlaps, identify possible synergies and adjust ministries' S&T budgets. Interactions with sectoral ministries. • A selection of important action plans (as defined by law) is reviewed by PACST Deliberative Council	• Translate the S&T Basic Plan and ministries' priorities into actions to be implemented during the year, with corresponding budgets • These plans also include sectoral actions not covered in the S&T Basic Plan (not reviewed by STI Office)
	Integrated annual S&T action plan	• Developed by the STI Office based on the ministries' annual plans	• Present in one whole-of-government document the action plans of all relevant ministries • Include a synthesis of the monitoring of the previous year's action plan
	Ministerial S&T programmes About 1 000 per year, including about 200 new programmes	• Developed and implemented by sectoral ministries New programmes • Comprehensive review by STI Office (consistency with Basic Plan and coherence with other programmes and budget) • Comprehensive review by PACST Deliberative Council's expert committees (assessment of the scientific and technological quality of	• Implement ministries' mid-term plans • Based on expert committees' opinions, the STI Office approves, rejects or adjusts ministerial programmes' content and budget

	Governance arrangements	Associated processes	Objectives
		the programmes) – hearing of responsible ministries by expert committees Ongoing programmes • Light review by STI Office	
3. Policy implementation	**Multi-ministerial R&D programmes** About 5-10 per year	• Review and selection of cross-ministerial R&D programmes by the Multi-ministerial Programme Committee, a permanent co-ordination structure under the PACST Deliberative Council, chaired by the Head of the STI Office	• Promote, guide and monitor cross-ministerial co-operation across the whole R&D programme cycle
	Pre-feasibility test of large-scale S&T programmes Currently for programmes above KRW 50 billion	• Performed by sectoral committees (under MSIT) that are chaired by the Head of STI Office for those related to R&D	• *Ex ante* assessment of the technological soundness and strategic relevance of large projects
	***Ex post* evaluation of S&T programmes**	• Performed by each responsible sectoral ministry • STI Office performs *ex post* evaluation of Special Programmes (defined by law), i.e. programmes considered critical due, for instance, to their large budgets or relevance to national priorities • STI Office also performs meta-evaluation of ministries' evaluations	• *Ex post* evaluation of ministries' programmes when completed • Review by the STI Office of the soundness of ministries' evaluations and approve or reject them
	"Impact-chasing" evaluation	• Performed by each responsible sectoral ministry and submitted to the STI Office • STI Office monitors the adequacy of the results and provides feedback if needed	• *Ex post* assessment of ministerial programmes at most five years after their completion to assess their impact and learn from their success and limitations

Annex 5.B. The different levels of programmes in the Korean administrative system

Annex Table 5.B.1. The different levels of programmes in the Korean administrative system

Level (tentative English translation)	Original Korean term	Number of items in 2020 (or latest data available)	Example
1. Programmes	프로그램	158 (in 2019)	Future fundamental technology development
2. Unit Programmes	단위사업	336 (in 2019)	Nanomaterial technology development
3. Specific Programmes	세부사업	1 022	Future material discovery
4. Internal Programmes	내역사업	n.a.	Metal materials
5. Projects	세부과제	73 501	Graphene-metal composite material for mass production of ultralight and large-capacity power lines

Source: Lee et al. (2020[42]), *Government R&D System Review and Policy Recommendations: A Case Study of the Biohealth R&D programs*, https://stepi.re.kr/common/report/Download.do?reIdx=984&cateCont=A0201&streFileNm=ffeb3213-ac3c-4aa0-8e26-fb0a3647a41f.pdf&downCont=0.

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Notes

1. Arnold and Barker (2022[90]) defines first-generation governance as the one that after World War II delegated the governance of science to scientists. In the second generation, the focus was put on different means of knowledge transfer as society demanded a social return from science through innovation and economic growth. The third generation aims to focus R&I on major societal challenges characterised by their complex and systemic nature.

2. This section draws on several sources, including (UNESCO, 1985[83]); (Bartzokas, 2005[91]); (Seong, 2011[6]); (Jang, 2012[94]); (Oh and Lee, 2013[7]); and (Hong, 2005[8]).

3. It is estimated that about 190 Industrial Research Associations were created in Korea between 1982 and 1997 (Sakakibara and Cho, 2022[4]).

4. The HAN Project aimed to increase the technological competitiveness of Korea to the level of G7 countries (hence the name, G7 Project). The project ran for ten years from 1992 to 2001. Its budget was KRW 3.7 trillion (around USD 3.5 trillion), including KRW 1.6 trillion (around USD 1.48 trillion) from the government and KRW 2.2 trillion (around USD 2.03 trillion) from the private sector.

5. The private sector represented 2% of the GERD in 1961, 3% in 1970 and 75% in 1985. Private sector R&D expenditures have exceeded public expenditures since 1983.

6. In Korean, *과학기술처*.

7. Notably, following the merger between MOST and MOE into MEST in 2008, the former STI Office (within MOST at the time) was reduced to a small bureau.

8. A large portion of MKE became the MOTIE. Other parts fell in the current portfolio of MSIT.

9. These are the 26 ministries for which R&I activities are co-ordinated by the Innovation Office in 2022. This number might vary in the case of changes in the government structure and reallocation of ministries' portfolios.

10. International comparisons are hazardous in this regard as ministries have different scopes. In Japan, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Economy, Trade and Industry (METI) account respectively for about 65% and 16% of the total R&D budget in 2020. In Germany, the Federal Ministry of Education and Research (BMBF) accounted for 56% of planned budgets (EUR 13.27 billion) in 2021, the Federal Ministry of Economics and Technology (BMWK) for 21% (EUR 4.97 billion) and the Defence Ministry for 7.5% (EUR 1.79 billion). Since MEXT and BMBF include universities in their portfolio, their share of R&D state budgets should be compared in Korea with the combined shares of MSIT and MOE (41%) to be meaningful.

11. The Defence Ministry, which acts rather separately from the rest of the system, is not taken into account in the rest of the report.

12. “Specific Programmes” (세부사업) are one category in the five-level administrative scale of programmes that ranges from “Projects” (the more granular administrative unit of action) to “Programmes” (the largest unit). While the size of these entities vary from one case to another in different areas and contexts, their number gives an indication of the order of magnitude at stake. There were 1 022 Specific Programmes in 2020 (see Annex 5.B, Annex Table 5.B.1..B.1).

13. The S&T Review Committee (1973-1996) headed by the Prime Minister and the S&T Ministerial Meeting (1997-99) headed by the Deputy Prime Minister of Economy and Finance, then the Ministry of S&T.

14. These changes have been analysed in depth in the 2009 OECD Review (OECD, 2009[10]).

15. To date, PACST’s main national strategies and plans include: Measures to build an information society (1993); Measures to improve the efficiency of the science and technology administrative system (1996); STI Promotion Plan to overcome the economic crisis (1998); Measures to strengthen the technological competitiveness of private companies to transform into the advanced economy (1999); S&T technology strategy following the fast rise of China (2002); Plan to provide demand-oriented support for the industry through industry-science collaboration (2005); Measures to improve global competitiveness of graduate schools (2011); Measures to create new energy industries in response to climate change (2014); Basic roadmap for the reduction of national greenhouse gas emission by 2030 (2016); and Measures to innovate the national S&T system (2018).

16. A professor from POSTECH during the term of the previous government.

17. The National Science and Technology Advisory Council Act.

18. For instance, in Sweden, the National Innovation Council is chaired by the Prime Minister and composed of 4 ministers (Environment and Climate; Finance; Business, Industry and Innovation; Higher Education and Research) and 12 representatives of R&I communities in a broad sense. It meets six times a year, of which two meetings are regional. Under the last government, the mandate was focused on providing advice on how Swedish society can address complex social challenges through innovation and co-operation.

19. The former president met with PACST three times during his term.

20. About ten of them come from MSIT and the rest are researchers from GRIs and universities.

21. The Committee is divided into two sub-committees, the S&T Committee and Innovative Ecosystem Committee, which make key decisions for the Vision.

22. The 1st Basic Plan included 67 projects; the 2nd Basic Plan 50 projects; and the 3rd Basic Plan 78 projects.

23. A more manageable set of national strategic technologies than the 4th Basic Plan, which included 120 core technologies.

24. These plans are also based on significant consultation. For instance, the development of the Industry Technology Innovation Promotion Plan for 2019-23 drew on 8 thematic committees gathering a total and 113 experts, who met 34 times. In addition, 669 people were met during on-site consultation meetings.

25. The exercises were carried out respectively in 1994, 1999, 2004 (2008), 2011 and 2016. They used to take place every five years until 2004. Since 2008, the foresight exercise results provide inputs to the Basic Plans.

26. In Korean, 중장기계획 조사·분석 결과.

27. In Korean, 중장기투자전략.

28. About half of the 90 sectoral mid-term plans are implemented via specific annual plans.

29. In Korean, 국가연구개발사업 예산 배분·조정안.

30. Major R&D programmes include basic/applied research, operating costs of GRIs and costs related to research facilities and procurement of equipment.

31. The programmes are all reviewed in about one month. The eight expert committees under the management committee of the Deliberative Council spend one week per year for the in-person budget review meetings.

32. The situation is further complicated by the fact that “programmes” and “projects” are often used alternately in English translations.

33. In Korean, 실 and 국 respectively (Ministry of Legislation, 2021[85]).

34. In 2020, 28 programmes went through the test, 24 in 2019, 31 in 2018, 12 in 2017 and 12 in 2016 (KISTEP, 2021[86]).

35. In 2021, Hwang, Park and Kim identified 17 agencies falling under the definition of R&D management agencies as defined in the National R&D Innovation Act of 2021. They performed their activities of planning, evaluation, and management of R&D projects under 13 ministries (Hwang, Park and Kim, 2021[47]). In 2020, a study for KISTEP listed 15 agencies (Hwang, 2020[92]).

36. Examples of these laws and regulations are: the Act on the Promotion of Science and Technology for Land, Infrastructure and Transportation (MOLIT), the Health and Medical Service Technology Promotion Act (MOHW), and the Act on the Promotion of Technology Innovation of Small and Medium Enterprises (MSS).

37. The next ones are 2022-24 and 2025-27; ANR is the French Ministry of Research and the French National Research Agency.

38. In Korean, 부처주도 다부처사업. Examples include the GoldenSeed project (Ministry of Agriculture and Food, Ministry of Oceans and Fisheries, Rural Development Administration and Korea Forest Service) and the Nano-convergence 2020 project (MSIT and MOTIE).

39. Formerly the Special Committee on Multi-ministerial Programmes, renamed in 2022 (Ministry of Legislation, 2022[57]).

40. For instance, in 2020, 79 programmes underwent specific evaluation. Examples include the Promotion of industrial foundation for hydrogen industry (MOTIE), Technology innovation R&D for SMEs (MSS) and R&D support for future materials (MSIT) (NTIS, 2022[87]).

41. In 2022, 146 programmes (accounting for a total of KRW 6.7 trillion) from 19 ministries were submitted for meta evaluation (PACST, 2022[88]).

42. For instance, KETEP has set up the “online meta evaluation” system. This is a unique online review tool that allows evaluators, applicants and management agencies to evaluate each other and verify how professional and fair their review and evaluation process is (IEA, 2020[70]).

43. In Korean, 과학기술 기반 사회문제해결 종합계획.

44. Health, environment, leisure, public safety, disaster control, energy, buildings and transportation, family, education and social cohesion (KISTEP, 2018[89]).

45. In absolute amounts, Japan is second to the United States, Germany is third and France is fourth (IEA Public energy RD&D database). In 2021, Korea’s energy RD&D represented 3% of the total IEA energy RD&D public spending (Japan accounted for 11%, France for 8%, and Germany for 6%) (IEA, 2021[84]).

46. In Korean, 기후위기 대응을 위한 탄소중립·녹색성장기본법.

47. In total, the commission has 55 commissioners, including 22 from the government (ministers from all ministries) and 33 from the private sector.

48. Each roadmap includes the decommissioning of the oldest 24 coal-fired power plants by 2034 and the phasing-out of all coal-fired power generation by 2050.

49. While currently available technologies can achieve the needed emission reductions targets of the 2030 commitments (45% reduction from 2010 levels), the net-zero objective for 2050 will require significant new advances and scale-up of technologies that are still in laboratories or at prototypeor demonstration stage (IEA, 2022[93]).

50. Another 600 000 jobs are expected in the new Korean New Deal 2.0, amounting to a total of about 2.5 million jobs by 2025 (the employed population in Korea was about 27 million in 2021).

51. Minister of Science and ICT leads DND, the Minister of Environment and Minister of Trade, Industry and Energy leads GND, and the Ministry of Employment and Labour leads HND.

52. In Korean, 국가 R&D 혁신·도전성 강화방안.

53. This initiative is not included in the scope of this review.

54. The programme is expected to be renewed for another period.

55. Three “theme-based programmes” were launched in 2022.

56. In Korean, 임무지향 R&D.

OECD Reviews of Innovation Policy

KOREA

The “Miracle on the River Han” catapulted Korea from developing country to a prosperous economy, driven in part by advancements in science, technology, and innovation. Being the second-highest R&D spender among OECD economies, Korea excels in key technologies, including semiconductors, 6G, and ICT infrastructure. Despite this remarkable progress, disparities remain between SMEs and chaebols, manufacturing and services, ICT and non-ICT industries, and urban and rural areas. Korea also grapples with societal and economic vulnerabilities, including an aging population, a significant carbon footprint, limited renewable energy use, and pronounced gender inequality. To further seize opportunities for equitable and inclusive growth, Korea must foster a shared national vision to develop science, technology, and innovation to address societal issues, enhance R&D policy implementation, promote excellent research, further internationalise, and broaden technology diffusion.

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