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Foreword

The OECD review of Luxembourg's innovation policy 2016 is part of a series of OECD country reviews of innovation policy.* It is the second of its kind, following the review published in 2007. It was requested by the Luxembourg authorities, represented by the Ministry of Higher Education and Research and was carried out by the OECD Directorate for Science, Technology and Innovation (DSTI) under the auspices of the Committee for Scientific and Technological Policy (CSTP).

The purpose of this review is to obtain a comprehensive understanding of the key elements, relationships and dynamics that drive the Luxembourg innovation system and the opportunities to enhance it through government policy. More specifically, the review:

- provides an independent and comparative assessment of the overall performance of the Luxembourg innovation system
- recommends where improvements can be made within the system
- formulates recommendations on how government policies can contribute to such improvements, drawing on the experience of other OECD countries and evidence on innovation processes, systems and policies.

The review is intended to be relevant to a wide range of stakeholders in Luxembourg, including government officials, researchers and entrepreneurs, as well as the general public. It also aims to use the OECD as a communication platform to provide an accessible and comprehensive presentation of the Luxembourg innovation system and policy to a global audience.

A draft version of the Overall Assessment and Recommendations was presented for a peer review to the Working Party for Innovation and Technology Policy (TIP) of the CSTP in December 2014. Emerging results of the review were presented to the Assises de la Recherche, held at the Cité des Sciences, Esch-Belval, Luxembourg, during the same month.

This report was drafted by Michael Keenan, Dimitrios Pontikakis (until December 2014), Giulia Ajmone Marsan (all Science and Technology Policy Division [STP], DSTI, OECD) with contributions from Morgan Meyer (consultant to the OECD; Agro ParisTech and INRA, France) and Michael Stampfer (consultant to the OECD; Vienna Science and Technology Fund, Austria) under the supervision of and with contributions from Gernot Hutschenreiter (STP, DSTI, OECD). Hermann Garden and Kathleen D'Hondt (both at STP, DSTI, OECD) provided valuable input. Ulf Sandström (consultant to the OECD; Sweden) contributed to the fact-finding missions to Luxembourg.

* www.oecd.org/sti/innovation/reviews.

The review draws on the results of a series of interviews with major stakeholders of the Luxembourg innovation system, and a background report commissioned by the Luxembourg authorities. This background report was prepared by Interface (Switzerland) and authored by Stefan Rieder, Milena Iselin and Olivier Dolder.

The review owes much to the support and co-operation of Luxembourg government officials, in particular Robert Kerger, Léon Diederich and Josiane Entringer (all Ministry of Higher Education and Research) as well as Mario Grotz, Gregory Saeul, Marco Walentiny (all Ministry of the Economy), who provided information and comments, arranged and hosted the interviews during the fact-finding missions in Luxembourg and provided invaluable support throughout the review process. The report has benefited from comments and additional information received from stakeholders in Luxembourg and the TIP peer review – in particular Ian Hughes (Forfás and Delegate to the TIP, Ireland) and Wolfgang Polt (Joanneum Research, Austria) who acted as peer reviewer – and distinguished experts in the field.

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Abbreviations and acronyms

AAGR	Average annual growth rate
AFR	Aide à la formation-recherche (Aid for Learning and Research)
BERD	Business expenditures for research and development
CIS	Community Innovation Survey
CEPS/INSTEAD	Centre d'études de populations, de pauvreté et de politiques socio-économiques (International networks for studies in technology, environment, alternatives, development)
CERE	Robert Schuman Centre for European Studies and Research
CHL	Centre hospitalier de Luxembourg
CNRS	Centre National de la recherche scientifique
CoC	Centre of competence
CRP	Centre de recherche publique (public research centre)
CVCE	Virtual Resource Centre for Knowledge about Europe
CVT	Centre de veille technologique
ECGS	European Centre for Geodynamics and Seismology
EMBL	European Molecular Biology Laboratory
EPFL	École polytechnique fédérale de Lausanne
EPO	European Patent Office
EPR	Employment Protection Regulation
EPO	European Patent Office
ESA	European Space Agency
ETH	Swiss Federal Institutes of Technology
EU	European Union
EUR	Euro
EUREKA	Raising the Competitiveness of European Business through Technology
FDEF	Faculty of Law, Economics and Finance
FDI	Foreign direct investment
FLSHASE	Faculty of Language and Literature, Humanities, Arts and Education
FNR	National Research Fund (Fonds national de la recherche)
FP	Framework Programme (European Commission)
FP7	Seventh Framework Programme, European Commission

FSTC	Faculty of Science, Technology and Communication
FTE	Full-time equivalent
FWO	Research Foundation Flanders
GDP	Gross domestic product
GERD	Gross expenditures for research and development
GNI	Gross national income
GBAORD	Government budget appropriations or outlays on R&D
GOVERD	Governmental intramural expenditures for research and development
GVC	Global value chain
HEI	Higher education institute
HERD	Higher education expenditures for research and development
IBBL	Integrated BioBank of Luxembourg
ICT	Information and communication technology
IF	Impact factor
IP	Intellectual property
IPRs	Intellectual property rights
IZM	Fraunhofer Institute for Reliability and Microintegration
KBC	Knowledge-based capital
KITS	Knowledge and Innovation Transfer Support programme of the FNR
LBAN	Luxembourg Business Angel Network
LCSB	Luxembourg Centre for Systems Biomedicine
LIH	Luxembourg Institute of Health
LISER	Luxembourg Institute of Socio-Economic Research
LIST	Luxembourg Institute of Science and Technology
LNS	National Health Laboratory
MECE	Ministère de l'Économie et du Commerce extérieur (Ministry of the Economy and Foreign Trade)
MFP	Multi-factor productivity
MNHN	Luxembourg Natural History Museum
MNE	Multinational enterprise
MPI	Max Planck Institute
NCER	National Centre of Excellence in Research
NCER-PD	National Centre of Excellence in Research on Parkinson's disease
NSF	National Science Foundation, United States
NTNU	Norwegian University of Science and Technology
OECD	Organisation for Economic Co-operation and Development
PC	Performance contract
PCT	Patent co-operation treaty

PD	Parkinson's disease
PhD	Doctor of Philosophy
PISA	Programme for International Student Assessment
PMR	Product market regulation
POC	Proof-of-Concept programme of the FNR
PPP	Purchasing power parity
P/PP	Public-private partnership
PRI	Public research institute
RCUK	Research Council UK
RDI	Research Development and Innovation
RIS3	Research and Innovation for Smart Specialisation Strategy
RTO	Research and Technology Organisation
R&D	Research and development
SINTEF	Norwegian Foundation for Scientific and Industrial Research
SME	Small and medium-sized enterprise
SNCI	National Credit and Investment Company
SnT	Interdisciplinary Centre for Security, Reliability and Trust
STATEC	Institut national de la statistique et des études économiques du Grand-Duché du Luxembourg (Luxembourg's National Statistical Office)
STI	Science, Technology and Innovation
SWOT	Strengths, weaknesses, opportunities and threats
S&T	Science and technology
TGen	Translational Genomics Research Institute, Phoenix, Arizona
UniGR	University of the Grande Région
UPF	Universitat Pompeu Fabra
USD	United States dollar
VAT	Value-added tax
VTT	Technical Research Centre of Finland

Executive summary

The overriding task of Luxembourg's innovation policy is to **strengthen innovation as a driver of sustainable growth and increased standards of living**. The Luxembourg government expects innovation to make important contributions to future productivity growth and to lead to further diversification of the economy through the development of new high value-added economic activities in non-financial services and manufacturing. High value-added activities tend to be technology- and knowledge-intensive and require investment in human resources, research and development (R&D) and innovation. The government has made significant investments along these lines, contributing to a **major transformation of the Luxembourg innovation system over the last 15 years**.

The first OECD review of Luxembourg's innovation policy, carried out in 2007, found a system in rapid transition. The Grand Duchy had just created the University of Luxembourg and established a new research funding council, the National Research Fund (FNR). The 2007 Review welcomed the government's objective of further **strengthening the public research base as a springboard for innovation-led growth**. Recommendations focused on improving the steering and funding of the public research centres (CRPs) and the university, and on upgrading governance arrangements to better coincide with the increased scale of R&D investment as well as the ambitious role innovation was expected to play in Luxembourg's future development.

Following the recommendations of the 2007 Review, major reforms have been implemented in the steering and funding of public research, notably the introduction of performance contracts for research funding and research performing organisations. The university has built from scratch some strong research bases that have a growing international reputation, while the CRPs have expanded their activities considerably. Public spending on R&D increased from EUR 137 million in 2007 to EUR 326 million in 2014 (an increase of 238%), **putting Luxembourg firmly on the map of European research**.

After this period of rapid, government-financed expansion, Luxembourg's public research system has now entered a period of consolidation. The government should build on the progress made over the past decade to promote Luxembourg as a widely recognised location for research and innovation in Europe. **Achieving sufficient critical mass in a small country setting** is a key challenge and will depend on strengthening the linkages between the university and the CRPs as well as their connections with users, including businesses and the public sector. It will also require a more strategic approach that better targets long-term funding to the most promising research areas and groups. This Review makes several specific recommendations along these lines, including the following:

Strengthen linkages in the innovation system

- Implement additional measures to **extend and deepen collaboration between the CRPs and the University of Luxembourg**, such as joint staff appointments (which would help build and strengthen co-operation between the two, e.g. through joint PhD supervision and research projects), specific provisions in the performance contracts or new co-ordination mechanisms that may now be feasible in light of the co-location at **the new City of Sciences** at Belval.
- Promote further the **international focus of the CRPs** by encouraging greater participation in EU funding programmes and greater co-operation with firms outside of Luxembourg.
- Consider further infrastructural investments so as to **ensure the City of Sciences at Belval has sufficient space and facilities** to co-locate all relevant parts of the University of Luxembourg and CRP research groups as originally planned.

Orient more strategically promising initiatives in the area of research and innovation

- Implement a **national innovation strategy** that strengthens the links between research investments and their likely impacts on the government's economic diversification, social well-being, and sustainability goals.
- Pay particular attention to implementation and introduce, if required, **funding and regulatory reforms** to enact the strategy's objectives. All of the main actors of the innovation system – including government ministries, agencies, other intermediaries, and research performers – should be asked to formulate and implement strategic organisational plans reflecting the national strategy's orientation and objectives.
- Update the **FNR's national research priorities** in line with the national innovation strategy and translate them into extra support for priority areas.

Raise the ambition of innovation activities in the business sector

- Consider adjusting some of the instruments promoting business-sector innovation so that they **better align with national sectoral and research priorities**. This would facilitate creating research and innovation public-private partnerships and help strengthen the national diversification strategy.
- Make **business R&D support more competitive and selective** and consider instituting competitive funding for larger, more strategic or collaborative projects in addition to current generic R&D support with low barriers.

Routinely **evaluate programmes and instruments** supporting business. Evaluation can improve the effectiveness and efficiency of innovation policy, particularly with respect to longer-term goals. Evaluating current innovation programmes would help strengthen the evidence base for future amendments of legislation on R&D and innovation. Making evaluations public would create awareness and facilitate learning.

Chapter 1.

Overall assessment and recommendations

This chapter presents an overall assessment of Luxembourg's innovation system and policy, reflecting key findings of the review. It reviews recommendations of the OECD Innovation Policy Review: Luxembourg 2007 *and their implementation and identifies strengths and weaknesses of the innovation system today. It sets out strategic tasks for innovation policy and develops specific policy recommendations for improving Luxembourg's research and innovation performance.*

1.1 Achievements and challenges – diversifying the economy and the role of innovation

Contributing to the great effort to overcome a long history of conflict on the European continent, Luxembourg has consistently played an active role in European political and economic integration. As a founding member of the Benelux group of countries, it has to this day helped advance and operate the institutions that constitute the European Union and the Economic and Monetary Union. The city of Luxembourg is the seat of several European institutions and agencies, including the European Court of Justice, the European Court of Auditors, and the Statistical Office of the European Communities (Eurostat). It also hosts the European Commission's Directorate-General for Translation and the Secretariat of the European Parliament. Luxembourg naturally participates in the Schengen group of countries, named after the Luxembourgish village of Schengen where the agreement facilitating free movement of citizens among member states was signed.

Over the course of the early 20th century, Luxembourg transitioned from a largely agrarian economy to an industrialised one with an important steel industry, which dominated in the aftermath of the Second World War until the oil and steel crises of the 1970s announced its secular decline. Even at the height of the steel industry, however, Luxembourg managed to attract a number of important multinational enterprises (MNEs) from other manufacturing areas. Beginning in the 1980s, the creation of new enterprises (supported by the newly established Société nationale de crédit et d'investissement), the development of industrial zones and other policies and initiatives mitigated the decline of the steel industry to some extent.

Luxembourg's second transformation, however – now towards a service economy – arose from the growth of its financial industry, clearly evidenced by the massive long-term shift in the structure of value added. Between 1970 and 2011, total industry's share in Luxembourg's value added declined from 47% to 8%, and that of steel from 28% to 2%. In parallel, the massive increase in the value added from the financial sector more than compensated for the decline of the steel industry. Financial-sector activity has been the main driver of economic growth in the past three decades. Luxembourg's banking sector is the largest in the European Union, accounting for roughly one-quarter of gross domestic product (GDP).

Luxembourg's development as a major global financial centre owes to a combination of a "first mover's" strategy in implementing international regulation, low taxation and strict banking secrecy rules. Luxembourg's financial sector comprises investment funds, insurance companies and banks. The country hosts the second-largest fund-administration industry globally. Most of the banks are foreign-owned subsidiaries that are weakly linked to the domestic economy through their operations. Numerous international companies are domiciled in Luxembourg.

Overall, Luxembourg's current macroeconomic situation remains favourable. The country enjoys the highest GDP per head[1] in the OECD, and its public finances are among the most solid. While real GDP growth remains well above the eurozone average, the unemployment rate has nearly doubled over the pre-crisis level. Reducing unemployment, especially among lower-skilled resident workers, is an important task. Reducing the economy's heavy dependence on the financial sector, which (as mentioned) has underpinned much of the growth of recent decades, is an overarching longer-term challenge.

The large financial sector has weathered the financial crisis relatively well, while posing challenges in aligning financial regulations with EU and international initiatives. Some fiscal and regulatory rules and practices that have provided Luxembourg with advantages in the past have come under scrutiny in the aftermath of the financial crisis. As many countries face tight budgetary constraints, international efforts to improve transparency (e.g. related to banking secrecy) have gained momentum, with some tax advantages being challenged or phased out. In such a context, diversifying its economy while maintaining a competitive financial sector has emerged more strongly as an important strategic issue for the future of Luxembourg.

1.2 The evolution of the innovation system: Following up on the *OECD Review of Innovation Policy: Luxembourg 2007*

The *OECD Review of Innovation Policy: Luxembourg 2007*, the first of its kind, found Luxembourg's innovation system in a state of significant transformation. Public research and development (R&D) expenditure had grown substantially in the years preceding the *Review* and (following an extended public debate) Luxembourg had just created its first university, the University of Luxembourg. The 2007 *Review* welcomed the Luxembourg government's objective of further strengthening and developing the public research base as a springboard for increased innovation-led growth. Specifically, it acknowledged the government's strong commitment to increase investment in R&D to bring the ratio of public R&D expenditure to GDP closer to the level of comparable OECD countries.

At the same time, the *Review* noted that the public institutions for funding, supporting and performing research and innovation – e.g. the National Research Fund (FNR), Luxinnovation, the public research centres (CRPs) and especially the University of Luxembourg – were all relatively young. It concluded that: "The innovation system is not yet fully developed. In some respects it is still unbalanced and needs to be adjusted to guarantee efficient use of an increase in public investment in R&D and innovation. At the same time there is great potential for future development, which is enhanced by a consensus among all relevant actors on the objectives and also the need for change in the institutional set-up and steering mechanisms". The *Review* further noted that the process of setting up the University of Luxembourg was obviously not complete and had proven more difficult than expected. It also found that the specialisation and division of labour between the CRPs, as well as their relation to the evolving university, had yet to be adequately defined.

Overall, the 2007 *Review* found that governance in the field of research and innovation was still rather weak, owing to a lack of objectives, strategies and state-of-the-art performance contracts to structure the governance of Luxembourg's public research centres (and other institutions). Consequently, major parts of the *Review* and the bulk of its recommendations focused on improving the steering and funding of CRPs and the new University, as well as lifting governance mechanisms to the level required by the increased scale of investment in R&D, the differentiation of the innovation system and the role innovation was expected to play in Luxembourg's future development – including in diversifying its economy.

The Luxembourg authorities decided to take on board all major recommendations made in the Overall Assessment and Recommendations of the 2007 *Review*. Table 1.1 summarises these recommendations and their subsequent implementation. This overview indicates that the commitment and responsiveness of the Luxembourgish government and

innovation actors turned the *Review* into an important step developing Luxembourg's innovation policy, with demonstrable and measurable impact on the design and performance of the innovation system.

After a period of rapid, largely government-financed expansion – especially in public research – and substantial reforms in the organisation and governance of the research and innovation system and its main institutional actors, Luxembourg has now entered a period of consolidation. This is the right time and opportunity to take stock of what has been achieved, and how to proceed further.

Table 1.1. **Recommendations of the 2007 Review and their implementation**

Summary of major 2007 recommendations	Implementation
– *Clarify the role of actors* in the research and innovation system by separating more clearly the policy formulation and implementation functions.	– Actors' roles were more clearly defined, particularly through the establishment and evaluation of performance contracts concluded with the public research performers and agencies. The creation of the Luxembourg Institute of Science and Technology (LIST) through the merger of CRP-Gabriel Lippmann and CRP-Henri Tudor and of a co-ordination mechanism among the research performers may contribute to this goal in the future.
– *Improve co-ordination among policy actors*, including among the major ministries in charge of R&D policies (Ministry of Higher Education and Research and Ministry of the Economy), and aim for better horizontal co-ordination of sectoral policies.	– The co-ordination between ministries (particularly the Ministry of Higher Education and Research and the Ministry of the Economy) has improved partly thanks to the new performance contracts. The previous formal Inter-ministerial Co-ordination Committee has become inactive.
– *Improve strategy formulation and management capabilities*, particularly at the ministries in charge – whose staffing should be increased – and rely more on external advice.	– The performance contracts, and their subsequent evaluations, reinforced strategy formulation and management capabilities of public innovation performers and agencies They have also been strengthened in the ministries, but staffing remains rather modest in view of an expanded and more complex innovation system.
– *Establish an Advisory Board on S&T Policy,* to be chaired either by the prime minister or one or several ministers. The Board's main task would be to monitor progress in implementing the government agenda for strengthening Luxembourg's research base, advising the government and initiating complementary studies and evaluations. The Board should comprise members with a strong background in business, science-and-innovation policy, including a sufficient number of non-residents.	– The Superior Committee for Research and Innovation was created in 2008 to support the development of national research and innovation policies and advise the government in implementing such policies. The Committee is co-chaired by the Minister of Higher Education and Research and the Minister of the Economy and Foreign Trade. Its other members are scientists, business people and civil-society representatives. The impact of the Committee has been limited.
– *Set science and technology priorities.* Building up the research base in Luxembourg requires a number of discretionary investment decisions that render a pure bottom-up approach insufficient. The ongoing Foresight Study should be used to derive priorities for such decisions. In the meantime, consultations with the end-users of research in preparation of the launch of Competence Centres could provide useful information for sharpening priorities for research at the University and the CRPs.	– The government has set six public research priorities based on the results of the 2006-07 Foresight Study. The priorities are addressed in the newly created CORE programme of the FNR and are part of the performance contracts of the CRPs and the Centre for Population, Poverty and Public Policy Studies (CEPS/INSTEAD). The University supports the priority-setting process through its own research priorities, which are partly in line with national-level priorities.
– *Steering of public research institutions.* Enhancing accountability and (ultimately) efficiency requires a clear mission statement for each CRP and agency; these mission statements should base themselves on strategic audits of the respective institutions. The current contractual arrangements between the government and public research institutions (e.g. the multi-annual programmes of CRPs) should be replaced by state-of-the-art performance contracts.	– The creation of performance contracts between the government and the CRPs, CEPS/INSTEAD, the agencies and the University of Luxembourg was a step change in improving governance. The contracts provide a framework for governance in the public research sector and are now in their third round. They enabled a shift to global budgets and multi-annual planning, with clear definitions of research priorities, goals and indicators, as well as evaluation and reporting schemes. The innovation performers and agencies perceive them as a useful instrument to structure and enhance governance while retaining institutional autonomy.

Table 1.1. **Recommendations of the 2007 Review and their implementation** (*continued*)

Summary of major 2007 recommendations	Implementation
– *A new role for Luxinnovation*. The agency plays an important role in Luxembourg's innovation system, especially by connecting business enterprises and public-sector research and ensuring greater participation of small firms in innovation. To maintain the quality of services in an environment of growing demand, the agency should streamline its current portfolio of activities and strengthen its organisational capabilities. It should play a key role in extending the reach of innovation policy to the service sector and other activities in which innovation does not directly rely on R&D.	– Luxinnovation's role has been adapted, but not fundamentally redefined. The introduction of performance contracts and external evaluation was an important change. The 2009 law on the promotion of research, development and innovation (RDI) highlights Luxinnovation's importance as a consulting and supporting institution. Its mission, objectives and portfolio have been refined accordingly. The appointment of a representative from the private sector as president may herald further reorientation.
– *Entrusting the FNR with all project and programme-based funding* of the CRPs and University of Luxembourg. The FNR has to fulfil an overly broad mandate mixing strategy and implementation.	– Much project and programme-based funding of CRPs and the University is now allocated by the FNR, with some notable exceptions, e.g. the significant funding channelled through the biomedical initiative.
– *Linking research to education*. This is a fundamental task of the University of Luxembourg, which should be facilitated by the establishment of research schools that can attract talented doctoral and post-doctoral students. However, the CRPs must complement the University's role by emphasising doctoral and post-doctoral training in their research units and ensuring the mobility of the highly skilled and trained workforce to the business sector.	– While the University of Luxembourg has a focus on research, much is performed in the two interdisciplinary centres, e.g. outside the teaching faculties. The University offers doctoral education through five doctoral schools (specialising in systems and molecular biomedicine; economics and finance; educational sciences; computer science and computer engineering; and law). The CRPs also host PhD students, though the majority are registered in foreign universities.
– *Promoting a coherent internationalisation strategy*. Internationalisation – in the "Grande Région" and beyond – is fundamental to the performance of Luxembourg research institutions and should be a key criterion for measuring the performance of CRPs. At the same time, performance contracts should ensure that the internationalisation strategy of CRPs is in line with their mission.	– While no formal overarching internationalisation strategy is in place, the University of Luxembourg, the CRPs, the CEPS and the innovation agencies have addressed many aspects of internationalisation. For example, the FNR operates the ATTRACT and PEARL programme to attract excellent researchers, as well as the INTER Mobility Programme promoting participation in international research projects, while Luxinnovation supports firms participating in European projects through Fit4Europe. Bilateral and multilateral co-operation agreements, as well as European RDI programmes, support internationalisation. The University of Luxembourg has entered into agreements with partner universities in Europe and worldwide and participates in a variety of EU programmes. The CRPs and CEPS are well connected to the international research community. Funding through European Framework Programmes was a recurrent issue in some evaluations, however. The FNR established co-operations with international peer organisations, e.g. the United States National Science Foundation. Luxembourg is a member of the European Space Agency and European Molecular Biology Laboratory, and participates in a variety of European Strategy Forum on Research Infrastructure projects.
– *Launching a Centres of Competence (CoC) programme* to promote sustainable long-term strategic linkages extending public-private interaction in research and innovation. CoCs are goal-oriented, long-term contractual arrangements between CRPs and firms, serving the needs of both sides. The rich international experience in this field could be used to design and implement a programme customised to Luxembourg's specific needs.	– A CoC programme has not been launched. However, the government has focused on public/private research collaboration and encourages establishing Centres of Excellence. The University's Interdisciplinary Centre for Security, Reliability and Trust (SnT) provides a platform for interaction and collaboration. Clusters promoted by Luxinnovation serve as networks of public and private stakeholders in the areas of space, materials, information communication technologies (ICTs), eco-innovation and biohealth. The Neobuild innovation cluster supported by the Ministry of the Economy is a private-sector initiative promoting R&D and innovation in sustainable construction. The FNR provides targeted support to public-private partnerships (P/PPs), e.g. in the CORE programme. The joint location of activities in the Cité des Sciences, de la recherche et de l'innovation (City of Sciences, Research and Innovation) in Belval is expected to result in synergies and facilitate P/PPs.

1.3 Main strengths and weaknesses of Luxembourg's innovation system today

Table 1.2 presents the results of strengths, weaknesses, opportunities, threats (SWOT) analysis of Luxembourg's innovation system.

Table 1.2. **SWOT analysis of the Luxembourg innovation system**

Strengths	Opportunities
– a high level of socio-economic development – an open economy, taking full advantage of its favourable location at the heart of Europe – a largely favourable regulatory environment and a responsive government – a dynamic and evolving research landscape – improved research system governance as a result of consolidation and well-designed performance contracts – a majority of firms routinely engaged in innovation – some strongly innovating MNEs – high-level recruitments that have boosted the research system's maturity and international visibility – strong research capabilities and links to socio-economic agendas in the University's interdisciplinary research centres – pockets of research strength in the CRPs, with good links to industry and professional practice – new research infrastructures, such as the Cité des Sciences in Belval, including teaching and research facilities and incubators.	– develop a national innovation strategy to improve direction-setting and coordination in the national innovation system – improve horizontal co-ordination (between the Ministry of Higher Education and Research, the Ministry of the Economy and the Ministry of Health) to promote policy effectiveness – improve contribution of public research organisations to innovation – provide stronger incentives for accumulating innovation capabilities within firms and extending their ambition – provide better support for business innovation through more professional implementation and a move towards project-level appraisal and instrument-level evaluation – enhance integration with high-potential international innovation networks, also beyond Europe – take full advantage of valorisation, e.g. by adopting a wider concept – see the Grande Région as an organising framework for policy initiatives that depend critically on proximity and critical mass (clusters, infrastructure, undergraduate programmes, etc.) – take advantage of the strong cluster emerging around the Biomedical Initiative and the SnT.
Weaknesses	**Threats**
– lack of a well-articulated strategy for directing innovation policy – occasional weak coherence and alignment between national priorities and those pursued by various actors – relatively low level of visibility and acknowledgement of Luxembourgish research actors at the global level – some weaknesses in accumulating further innovation capabilities and extending the reach and ambition of innovation in parts of the business sector – lack of critical mass of internationally excellent research, especially in CRPs – low levels of business R&D, concentrated in a limited number of big players – weak intensity of PP/Ps and collaborations, at least by other advanced-economy standards – relatively low participation in EU Framework Programmes compared to other advanced economies – lack of visibility of research performed in the University faculties – under-developed linkages between the University and CRPs.	– lack of progress in economic diversification – stagnation or decrease of business R&D investments – inability to further expand the system for the longer term owing to stagnating public financial resources – research actors disconnected from the rest of the economy – lack of public understanding of the benefits of local spillovers arising from public research actors – increasing difficulty in attracting and retaining highly skilled workers in the face of mounting global competition.

1.4 Strategic tasks

The overriding task of Luxembourg innovation policy is to strengthen innovation as a driver of sustainable growth and maintain and increase the population's high standards of living. Innovation policy can make important contributions to solving major strategic tasks the country's faces.

- *Achieving and maintaining adequate productivity growth.* Productivity is recognised as the main driver of economic development in the long term, and the major source of differences across countries in GDP per capita, notably for

high-income countries. Luxembourg's high living standards are supported by its high level of labour productivity. Multifactor productivity (MFP), e.g. the joint efficiency of the production inputs, labour and capital, growth is the most important driver of labour productivity growth. For the most developed countries, innovation tends to be the main driver of MFP growth. Thus, long-run economic performance depends on the level and quality of its innovation activities.

- *Diversifying the Luxembourg economy within the financial sector but also through the development of new high value-added economic activities* in non-financial services and manufacturing industries. This would help to reduce, over time, the economy's heavy reliance on the financial sector. In the aftermath of the crisis, it has become widely acknowledged that diversification could contribute to strengthening the resilience of the economy and mobilising new sources of growth, notably through innovation-driven economic activities. High-value-added activities tend to be technology and knowledge-intensive, and require investment in human resources R&D and innovation.

After a period of rapid, largely government-financed expansion of the research and innovation system – especially in public research – and substantial reforms in the organisation and governance of the research and innovation system and its main institutional actors, Luxembourg's innovation system is now entering a new phase. Major tasks to be addressed in this next phase include:

- to consolidate the progress Luxembourg made over the past decade, and advance further to become a widely recognised location for research and innovation in Europe
- to better link and orient more strategically the promising initiatives in the area of research and innovation that have been initiated and flourished during the recent period of rapid growth and change
- to improve governance and steer the innovation system in a way that:
  - enhances co-ordination across ministries and agencies
  - strengthens linkages between public research centres (the CRPs) and the University of Luxembourg
  - helps better target long-term funding to the most promising research areas and groups.

1.5 Key issues and recommendations

Taking due account of Luxembourg's innovation-related SWOT and the strategic tasks to be addressed by innovation policy, this report has identified a number of key issues leading to some policy recommendations.

Promoting critical mass, excellence and relevance in public research

Over the last decade, the Luxembourg government has accelerated its investment in public-sector research and made new investments in research infrastructure, notably the Cité des Sciences at Belval. The University of Luxembourg is now the largest public-sector research performer, followed by the CRPs. While the University has grown greatly over a short period, the CRPs have also expanded significantly. Bibliometric

analysis suggests that the public research sector's output has increased, with a generally positive trend in its international impact.

Government chiefly funds the University of Luxembourg and CRPs through block grants from the Ministry of Higher Education and Research and competitive funding from the FNR. The Ministry of Higher Education and Research block grant is governed by performance contracts with each of the CRPs and the University (see below). FNR funding – which has grown markedly – is directed through several schemes emphasising research excellence, notably the thematic programme CORE, the Aides à la formation-recherche (AFR) funding programme for PhD and post-doctoral research, and the INTER, ATTRACT and PEARL mobility programmes.

The University of Luxembourg

The University of Luxembourg conducts research in its three faculties – the Faculty of Science, Technology and Communication; the Faculty of Law, Economics and Finance; and the Faculty of Language and Literature, Humanities, Arts and Education – as well as in two semi-autonomous interdisciplinary centres founded in 2009 – the Interdisciplinary Centre for Security, Reliability and Trust (SnT) and the Luxembourg Centre for Systems Biomedicine (LCSB). In 2013, the University secured almost EUR 30 million in third-party funding for research, up from EUR 16 million in 2010. By the end of 2013, the University had a total staff of 1 460, 16% of whom are faculty members and 57% other scientific and research staff.

Reflecting its ambition to achieve international visibility in a few research areas, the University of Luxembourg has a limited number of research and teaching priorities. These are revisited every three or four years, with some continuity – but also some differences – with earlier articulations of priorities. The faculties include several research units whose activities may or may not be aligned with the University's strategic research priorities. For example, the Faculty of Science, Technology and Communication (which employed around 350 R&D personnel in 2013) features five research units – computer sciences and communications, engineering sciences, mathematics, physics and materials sciences, and life sciences; of these, only two are aligned with the University's current strategic research priorities on computation sciences, and physics and materials. The 2013 evaluation of the University of Luxembourg highlighted the lack of visibility of faculty research compared with research performed in the interdisciplinary centres covering the University's strategic research priorities. Still, the faculties continue to account for the largest part of the University's block grant.

The two interdisciplinary centres, LCSB and SnT, warrant special attention, as they have grown rapidly and are increasingly visible at the international level. The LCSB originated in the Luxembourg government's Health Sciences and Technologies Action Plan and was built through a partnership with leading US institutes specialising in systems biology (see below). Its aim is to carry out fundamental research in the field of systems biology and biomedicine and to analyse the mechanisms of disease pathogenesis, with a special focus on neurodegenerative diseases and more specifically on Parkinson's disease. By the end of 2013, the LCSB employed more than 140 R&D personnel, including only 7 faculty members; the remainder are supported by a mix of University priority funding, FNR studentships and fellowships, FNR research grants, EU Seventh Framework Programme/Horizon 2020 funding, and funding from other national sources. In 2013, the LCSB secured more than EUR 13 million in research grants. According to the scientific review panel associated with the 2013 evaluation of the University of

Luxembourg, the LCSB fills a niche that is not yet over-populated. The panel was impressed with its performance, judging it to be "very good" and firmly on track to become "excellent". At the same time, the panel raised concerns about inadequate facilities at Belval and the need to improve collaboration with other parts of the University, notably related research units in the Faculty of Science, Technology and Communication.

The SnT was created to take the lead on implementing the University's focus on information technology security and reliability. This priority is particularly pertinent for Luxembourg, which has for some time sought to position itself as a European centre of excellence for secure, reliable and trustworthy ICT systems and services. Like the LCSB, the SnT has experienced fast and steady growth in terms of staff members, PhD students, industry partners and public grants since its creation in 2009. By the end of 2013, it numbered 222 R&D personnel (including PhD students and interns), including 17 faculty members. A key defining feature of the SnT is its Partnership Programme, where key actors contribute know-how and resources to shape and build the SnT; 20 such partnerships involving a mix of public and private organisations already existed in 2013. That year, the SnT spent EUR 11.5 million on R&D; externally funded projects accounted for 69% of research revenues, mostly funded through various FNR schemes, but also through the Partnership Programme (16%). The Programme is notable for relying upon strategic mid- and long-term research partnerships with strongly committed industry or research players, rather than on short-term service-type projects that are more typical of the industry relationships permeating the more applied research-oriented CRPs. The SnT strategy holds that public funding for high-risk fundamental research should find an articulation with, and not be done separately from, more practice-oriented projects with partners. The scientific review panel associated with the 2013 evaluation of the University recommended expanding partnerships further afield – starting with stronger relationships with international institutes – to drive excellence. It also highlighted the unclear division of labour with the Faculty of Science, Technology and Communication and its focus on academic research.

The interdisciplinary centres have undoubtedly proven successful so far and have provided a major boost to the University's research profile. Their independent status lends them considerable agility and has allowed them, for example, to install swift recruitment procedures and expand very rapidly. At the same time, such autonomy risks disconnecting them from the faculties and weakening the links between research and teaching activities. Differences in contracts, distribution of workload and promotion tracks contribute to tensions between interdisciplinary centre staff and faculties. Tensions also arise over the University allocating the bulk of its block grant to the faculties, despite the interdisciplinary centres' strong research performance.

The 2013 evaluation of the University of Luxembourg highlighted the need for a common understanding of "research quality" and the means to monitor, improve and reward it, as well as clarity on the meaning and utility of research priorities. The evaluation recommended that the University's central administration develop, together with all parties concerned, a clear and balanced strategy on the relationship between faculties/research units, the interdisciplinary centres, and the University's overall priorities, also taking into account the relationships between research, teaching and valorisation. This strategy has yet to be developed; notwithstanding the pressures of the upcoming move to Belval, it should be articulated and implemented as soon as possible.

A further priority for the University of Luxembourg is establishing a School of Medicine. Currently, neighbouring countries accept medical students from Luxembourg, with the University providing the first year of medical training. Luxembourg would be less dependent on foreign medical education providers if it had its own medical school, adapted to its own health system and featuring strong links between teaching and research – particularly in the fields of biomedicine and translational research. Proceeding along these lines presents benefits, but also considerable constraints that need to be considered. First, establishing a medical school would be a very expensive endeavour, consuming a large part of the University's budget while providing training for just 25-50 students a year. Second, productive links between teaching and research are most likely to emerge in advanced and postgraduate studies rather than in the first years of medical teaching, so linking research and teaching might not prove as beneficial as expected. Finally, important complementary assets – such as the ready availability of medical doctors with extensive teaching experience – appear to be under-developed. The University and Ministry of Higher Education and Research have each commissioned studies to assess the advantages and disadvantages of creating a medical school in Luxembourg; they will report their results in 2015.

Recommendations

- *Articulate and implement an inclusive whole-of-university research strategy within the University*. Among other things, the strategy should aim to set University research priorities: define the meanings, relevance and implications of research excellence; delineate a fair reward system for research excellence and relevance among faculty research units and interdisciplinary centres; clarify the relationships between interdisciplinary centres and faculties; consider the merits of establishing further interdisciplinary centres; and define relationships with external actors, including the CRPs and international research partners.
- *Consider carefully the options for setting up a medical school at the University*. The many potential benefits of establishing such a school should be weighed against the very substantial costs involved.

Public research centres (CRPs)

The R&D law of 1987 established three major public research centres: CRP Gabriel Lippmann, CRP Henri Tudor and CRP Santé. Since 2015, CRP Gabriel Lippmann and CRP Henri Tudor have merged to become the Luxembourg Institute of Science and Technology (LIST), and CRP Santé has been renamed the Luxembourg Institute of Health (LIH). LIST research focuses on three main areas – environment, information technology and materials – while LIH focuses research on clinically-oriented biomedical research and public health. The Luxembourg Institute of Socio-Economic Research (LISER) (formerly CEPS/INSTEAD) performs both basic and applied research in areas such as population and employment, geography and development, and business and industrial organisation with the aim of informing social policy making in Luxembourg. All these centres are under the direct responsibility of the Ministry of Higher Education and Research.

The merger of the Gabriel Lippmann and Henri Tudor CRPs seems appropriate in light of the high degree of overlap and contemporary changes in the wider system, including the new infrastructures in Belval. It represents an opportunity that should be fully exploited to address past issues and seize future opportunities. A new CRP law (2014) cements the status of the CRPs as autonomous public legal entities with financial

and administrative autonomy, and alters the terms of their relationship with the Ministry of Higher Education and Research. The law also formally updates their missions to promote knowledge and technology transfer, training and lifelong-learning, and scientific co-operation at national and international levels; it also introduces more transparent and open recruiting procedures.

Although the CRPs were originally established to support service-oriented applied research to meet business-sector needs, they have increasingly focused over the past 25 years on more strategic applied – and occasionally basic – research. This shift derived from a significant increase in public investment in the CRPs and has led to hundreds of new researchers arriving in Luxembourg in recent years. While the block grant has increased continuously in absolute terms, its relative share in the budget of the CRPs has been declining. Performance indicators for the overall CRP sector reveal difficulties in attracting competitive and contractual research funding, especially from European sources. The CRPs received about 10% of European FP7 funding (up to August 2014) – approximately half of the funding received by the University of Luxembourg over the same period. The success of SnT in securing long-term industry funding through its Partnership Programme leads to questions about the difficulties of CRPs in meeting their targets for attracting contractual research funding. More positively, the CRPs have secured a sizeable number of the AFR doctoral and post-doctoral grants provided through the FNR. The CRPs have also benefited from the PEARL and ATTRACT programmes of the FNR to attract – though only to a minor extent – top international talent to Luxembourg.

According to recent evaluations, the CRPs and the University of Luxembourg could significantly enhance their interaction. For example, very few of the PhD students at the CRPs are enrolled at the University of Luxembourg, and joint staff appointments are extremely rare. Various institutional arrangements at the University that appear to hinder greater co-operation are currently under review or revision; co-location at Belval is likely to offer new opportunities for closer collaboration. Luxembourg could learn from experiences in many advanced European countries, where deep and extensive ties exist between universities and CRP-like public research institutes.

The roles of the CRPs continue to be contested – in the same vein as with similar institutions in other countries – not only owing due to the breadth of activities in which they engage, but also because of recent institutional changes in the wider innovation system. The CRPs serve considerably different functions than those of the University of Luxembourg. For instance, providing support to evidence-based policy features prominently in the mission of both LISER and LIST (which also has the explicit objective of strengthening business-innovation capacities). While their distinct missions are to some extent reflected in the performance contracts, the sorts of activities they engage in are notoriously difficult to measure and account for using rigorous performance indicators. The performance indicators on international scientific excellence are less questionable – and here, the CRPs are facing increasing pressure to improve their scientific output. The number of scientific outputs has grown for all CRPs; however, the impact and number of citations of these publications are not exhibiting similar growth, especially in the case of LISER and the former CRP Henri Tudor.

Recommendations

- *Promote further the international focus of the CRPs* by encouraging greater participation in EU funding programmes and greater co-operation with firms outside of Luxembourg. This could be a core part of efforts to improve

international scientific excellence in a framework of socio-economic relevance. The creation of LIST creates good conditions for a next step in this direction. Prepare this shift with a broad discussion on the level of ambition, geographical scope and further specialisation of public research actors.

- *Consider carefully the possibility of additional mergers in light of the experience of the merger of CRP Gabriel Lippmann and CRP Henri Tudor into LIST.* Merging LIH and LISER either with the University of Luxembourg or with LIST would require considerable time to prepare and should be carefully evaluated, taking into account the relative merits of grouping researchers, creating critical mass and reducing administrative costs.
- *Implement additional measures to extend and deepen collaboration between the CRPs and the University of Luxembourg*, such as joint staff appointments, specific provisions in the performance contracts or new co-ordination mechanisms that may now be feasible in light of the co-location at Belval. Joint senior staff appointments between the University of Luxembourg and CRPs in particular would help build and cement co-operation between the two, e.g. through joint PhD supervision and joint research projects.
- *Explore what lessons can be learnt from the approach taken by the SnT* to resolving tensions between academic and user-oriented research in the same institute, bearing in mind the somewhat different missions, histories and legacies of the CRPs.
- *Revisit the choice of performance indicators used for some of the core functions performed by the CRPs*, as they may be intrinsically difficult to compare systematically over time. Selecting complementary assessment methods, including evaluations by clients or other stakeholders, may be preferable when it comes to these functions.

Cité des Sciences infrastructure at Belval

The large-scale infrastructure development at the former industrial site of Belval is an important milestone in the continuing efforts to consolidate and upgrade the public research system. It is one of the largest and most ambitious current urban-renewal projects in Europe, with a budget close to EUR 1 billion. It is expected to house over 6 000 inhabitants, sustain over 20 000 new jobs, and become the studying and working place of about 7 000 students and 3 000 researchers and lecturers. The Cité des Sciences at Belval aims to assemble most of Luxembourg's public research organisations (including the University of Luxembourg) and most of the public research centres (including LIST and LISER) in one place. For historical reasons, the University of Luxembourg is currently located in four sites. This dispersion limits communication, synergies (e.g. interdisciplinary work and consolidation of common functions) and critical mass. Most of the University is expected to move during 2015-16.

Once complete, Belval should have numerous functionalities: it will co-locate the so-called "knowledge triangle" of research, teaching and innovation. It will also feature residential, commercial, industrial, sports and leisure facilities. Newly built facilities will also house private firms involved in research as well as support P/PPs, e.g. the Technoport and House of BioHealth (see below). Nevertheless, the conditions that make for a vibrant knowledge community are difficult to recreate. Concerns have been voiced about the site's apparent lack of space to house the research groups that are supposed to

move there over the next few years. This jeopardises Belval's original aim to co-locate researchers working in similar areas, independent of their organisational affiliation, and instead risks raising tensions about which group should get the most space. The quality of public transport links with Luxembourg City is also under question.

Recommendations

- *Ensure Belval has sufficient space and facilities to co-locate University of Luxembourg and CRP research groups as originally planned.* This may require further infrastructural investments so that the initiative may deliver on its aims of creating critical mass and excellence in chosen research areas.
- *Establish mechanisms to monitor the evolution of Belval* in light of its social and economic functions, *allow continuous learning* from international experience and *co-ordinate responses* to the challenges identified.
- *Acquire a better understanding of the implications of locating public research units within thematically organised "houses"*, shifting away from their current location around centres and faculties. Opportunities may arise in terms of interdisciplinarity, some institutions could be reconfigured once researchers start working in the same buildings, and previously unforeseen possibilities for co-operation may emerge.
- *Ensure Belval is appropriately branded and promoted internationally*, since the *Cité des Sciences* offers unique opportunities to raise the international visibility and attractiveness of research and innovation activities in Luxembourg.

Valorisation

The University's guidelines on valorisation define it as "all initiatives and activities undertaken with a view to increasing the value of research results and, more generally, enhancing knowledge". Academic engagement with industry involves multidirectional knowledge-related collaboration through formal (e.g. collaborative research, contract research and consulting) and informal activities (e.g. networking and exchanges at conferences and other forums). Although sometimes measured through patenting and licensing of inventions, as well as academic entrepreneurship (e.g. spin-offs), valorisation does not only occur at the end of a research project or programme. Instead, it is the result of interaction between a variety of research and innovation actors at different stages of research and innovation.

Considerable effort is under way in Luxembourg to improve the valorisation capabilities of public research actors and provide adapted institutional and physical infrastructures. The FNR seeks to promote knowledge transfer from public-sector research to the business sector through collaborative research programmes involving P/PPs. For example, its two largest programmes, CORE and AFR, support P/PPs. The FNR is regularly criticised for not doing more to support P/PPs, particularly with regard to its procedures for scientific excellence, and is currently rethinking its approach.

Luxinnovation also has several activities and programmes promoting knowledge transfer between firms and public-sector research organisations. It regularly organises networking events and actively helps businesses find the right research partners in the public research landscape. It also has a dedicated programme supporting innovative start-ups and assisting companies on intellectual property (IP) matters.

Many of the relevant infrastructures for promoting spin-offs and IP from public research are already or will be located in Belval. These include Technoport, the House of Biohealth and a new FNR-funded initiative in SnT. Co-location in Belval will provide an opportunity for researchers, academics and students to interact and benefit from local knowledge spillovers. Other structures promoting technology transfer and valorisation are hosted by the University of Luxembourg and the CRPs.

The performance contracts include valorisation indicators, e.g. the number of patents, spin-offs, prototypes, contract research and licensing income. These indicators do not indicate a clear trend, given their low numbers and a limited number of observations. Moreover, they do not capture the valorisation activities occurring through collaborative research, personnel exchanges, mobility programmes or other channels and forms of knowledge transfer that are equally important to innovation. Few internationally comparable indicators of the economic relevance of public research are available, but those that exist suggest weak valorisation. For example, industry financed just over 1% of higher education R&D in Luxembourg, compared with 6% on average across OECD countries. Further, Luxembourg's performance in terms of the number of patents filed by public research institutions stands well below that of most other OECD countries.

All in all, while these efforts appear to be bearing some fruit, the impact of valorisation activities seems low by most accounts. This is not surprising, given that valorisation-minded policy has only gained momentum over the past decade. It is even less surprising considering that the economic impact of most *measurable* traits of valorisation (e.g. spin-offs and patents) is weak even in advanced innovation systems, where valorisation mostly occurs in the form of unmeasurable spillovers from training, collaboration and human-resource mobility.

Recommendations

- *Adopt realistic expectations around valorisation*, learning from international experiences. This pragmatism relates closely to the government's ambition to diversify Luxembourg's economy, which should acknowledge the limits of "science-push" approaches. In this regard:
  - *Utilise a broad conceptualisation of valorisation in policy making*, acknowledging the important roles played by teaching, consulting, policy advice, etc., in knowledge transfer from public-sector research. Moreover, valorisation policy should not focus solely on research commercialisation, but also target public research's contribution to clinical practice, public regulation, etc.
  - *Learn from international good practice* on maximising the impacts of the commercialisation infrastructures at Belval. Many countries have more than two decades of experience in developing and maintaining such infrastructures, and have useful lessons to relay.
- *Broaden the appeal and openness of the FNR to P/PPs*. Including industry representatives and other users in all FNR panels (as is done in many other countries) is one means to this end; another is joint programming with the Ministry of the Economy targeting P/PPs in need of larger private-sector contributions.

Building a world-class human-resource base for science, technology and innovation (STI)

Luxembourg has a highly educated population. Its high share of tertiary-educated adults (40%, just behind Finland) almost doubled between 2000 and 2012. However, the quality of secondary education could be improved. In the 2012 OECD Programme for International Student Assessment (PISA) assessment of 15-year olds in mathematics, reading and science, Luxembourg had a mean performance just under the OECD average and below that of most other countries with advanced innovation systems (except for Norway).

Luxembourg features very high (inward and outward) workforce mobility. A large share of the workforce lives outside Luxembourg. Despite the establishment of the University of Luxembourg in 2003, most Luxembourgers still receive their tertiary education abroad. A small majority of University of Luxembourg students are non-nationals – many of whom, however, are long-term residents of Luxembourg. University of Luxembourg bachelor degree programmes have a compulsory mobility component that has seen increasing numbers of students study outside of the Grande Région. In the area of public R&D, more than 80% of researchers are non-Luxembourgers, but there are some indications that a number of research institutes favour nationals of neighbouring countries. Since science is a global endeavour, attracting talent from further afield will be important in the longer term.

Gender imbalance appears to be an issue. Just 24% of researchers (headcount) in Luxembourg are women. The situation is especially unbalanced in the business sector (11%) but better in the CRPs (36%) and the University of Luxembourg (39%). There are no programmes currently addressing this issue.

Almost 6 200 students enrolled at the University of Luxembourg in 2013/14 – a 20% increase over 2009/10. The most popular subject group is business and administration (24% of all students), followed by education (16%), humanities and arts (12%), science, mathematics and computing (12%), law (12%), and social and behavioural sciences (11%); engineering lags far behind, accounting for just 4% of students. However, dropout rates are relatively high and some courses are well under-subscribed. Most students (53%) are pursuing a bachelor's degree, 19% are studying towards a master's, 9% towards a PhD and 19% are enrolled in other programmes (e.g. diplomas and certificates). Postgraduate programmes have grown the most rapidly in recent years: master's enrolments soared from 259 in 2006/07 to 1 183 in 2013/14, while PhD enrolments rose from 148 in 2006/07 to 545 in 2013/14.

Policy has placed considerable emphasis on strengthening the human-resource base for research. In 2013, the FNR funded 99 AFR PhDs and 49 post-doctoral places for a total of EUR 29 million. The FNR PEARL programme aims to attract high-calibre researchers to Luxembourg by offering them five-year research grants; it selects an average of one or two candidates a year (for a total grant amount of EUR 3-4 million), to be recruited by either the University or the CRPs. The FNR ATTRACT programme operates in a similar fashion to PEARL, but is aimed at younger researchers. In 2011-13, the FNR funded 4 ATTRACT projects for a total of about EUR 6 million – below the total allocated budget. Its INTER Mobility Programme promotes scientific exchanges between research groups located in Luxembourg and abroad. It supports both researchers working in Luxembourg wishing to go abroad and researchers working abroad wishing to join public research groups in Luxembourg.

In addition to the instruments described above, the FNR runs several programmes to improve public understanding of science and promote science among students of all ages. These are focused particularly on increasing the attractiveness of research careers among Luxembourg's youth. The FNR has conceived a number of initiatives – including Go for Science (promoting joint activities between universities and schools), ProScience (focusing on awareness raising), the information website science.lu, the school contest GENIAL!, the Science Festival, Researcher's Days, and a variety of other children's programmes – to encourage young people to become scientists or engage in scientific activities at an early age.

Recommendations

- *Review the scale and scope of undergraduate teaching at the University of Luxembourg and its fit with local labour-market needs.* Some courses are under-subscribed and could perhaps be delivered in partnership with other institutes in the Grande Région.
- *Consider introducing a national initiative to promote more women in science in Luxembourg*. This could be led by the Ministry of Higher Education and Research and the Ministry of the Economy and would involve research performing organisations and the FNR taking steps to improve the gender balance of researchers.
- *Develop clear research career routes (including tenure tracks) to improve Luxembourg's attractiveness to the most promising researchers.* This will likely require developing a portfolio of schemes for different career stages, administered by research performing organisations and the FNR.

Improving public governance – steering and co-ordination

Setting national priorities

Luxembourg's small size means it is unable to pursue a wide range of research areas in the same manner as larger advanced economies. The areas pursued should have "critical mass", e.g. they should be of sufficient size and depth to produce very good or excellent research that is (for the most part) internationally visible. The government has also signalled through its funding approach that research should have high socio-economic relevance, and has designed and implemented a mix of action plans and research priorities to channel large portions of public spending towards research. For example, sectoral action plans exist for healthcare technologies (see below), eco-technologies and logistics; they are part of a "multi-specialisation" strategy that seeks to diversify Luxembourg's economy and reduce its dependence on the financial sector.

The FNR conducted a foresight exercise in 2006-07 and identified several "national" research priorities targeting a small number of thematic areas; these are organised into five broad categories, which have been used to concentrate funding in its largest funding scheme, the thematically oriented CORE programme. Some areas of existing research competence in Luxembourg are excluded, notably law and mathematics, where the University has strengths. The FNR recently introduced the OPEN programme, a modest new project-funding scheme aimed at researchers in the excluded areas.

There is considerable debate in Luxembourg on the merits, meaning and status of FNR national research priorities, which do not perfectly align with the sectoral action plans and clusters promoted by the MECE and Luxinnovation. This is understandable: not

all sectors and clusters necessarily have strong links to public research, and it would be unwise to try to force alignment along these lines. Nevertheless, where there is overlap, e.g. in biomedicine and smart materials, alignment and co-ordination would be expected.

There is also some misalignment with the research areas pursued in the University and CRPs. In some fields – e.g. biomedicine, ICTs and smart materials – emerging strong research capabilities in the University and CRPs indicate good alignment, but that is not the case in other fields (e.g. sustainable resources). Since the FNR accounts for just one-fifth of national public research funding in Luxembourg, it has limited leverage over the research areas pursued by the University and CRPs. The bulk of public funding to the University and CRPs is still channelled through Ministry of Higher Education and Research block grants, which they are free to allocate internally themselves. A more strategic alignment of University and CRP research profiles with national priorities would likely need incentivising. This could be done through "top-slicing" of block grants for specific priorities and/or by channelling a larger proportion of public research funding through FNR's thematic programmes. Some form of national research assessment exercise, including criteria on excellence, relevance and critical mass, could also be launched. While such mechanisms would encourage the University and CRPs to consolidate their research profiles, they have their pros and cons and are likely to be controversial. They would need to be carefully considered as part of a wider debate on steering the research system.

There is also discussion on the number and breadth of FNR national priorities. One argument holds that fewer and /or narrower research priorities could allow Luxembourg to develop the critical mass needed to be a major international research player in perhaps one or two chosen fields, and that these priorities should be selected based on their promise of sizeable economic returns in the near future. The action plans mentioned above have already taken this approach in many respects. However, given the uncertain nature of research, this overly specialised approach is too narrow for a national funding agency, which should maintain some variety in its support. While aiming for critical mass is also important, its meaning will vary considerably among fields – e.g. in terms of the size of research groups, the equipment they need, and the sorts of links they should have internationally and with socio-economic actors to realise their ambition. Debates on priorities also extend to the types of support measures that are most appropriate for building and maintaining critical mass in a small variety of research fields; the current FNR portfolio of support measures seems appropriate in this regard. There also appears to be flexibility to assign extra resources to a few chosen priority areas. For example, the FNR recently announced a new pilot scheme, the National Centres of Excellence (NCER) programme, to provide long-term funding to consortia of leading scientists to address ambitious scientific and socio-economic goals.

Overall, Luxembourg would benefit from regularly revisiting the issue of national priorities in terms of their necessity, formulation and implementation. For this purpose, most advanced OECD countries prepare dedicated national innovation strategies on a five- to ten-year cycle. Such an exercise should include a clear articulation of the rationales for prioritisation, as well as for the priorities chosen. National research priorities should be aligned with other national innovation-related priorities as appropriate. The government will need to pay special attention to implementation and perhaps make changes to the funding system, e.g. by providing incentives to the University of Luxembourg and CRPs to strategically consolidate their research profiles and step up their co-operation.

Recommendations

- *Implement a national innovation strategy* that articulates the links between research investments and their likely impacts on the government's economic diversification, social well-being, and sustainability goals. In this regard:
  - *Ensure the strategy process is inclusive, reflective, forward-looking and comparative*. It should lead to articulating clear statements on models, expectations of outcomes, priorities, objectives and the expected roles of the main innovation actors.
  - *Pay particular attention to implementation* and introduce as required funding and regulatory reforms to enact the strategy's objectives. All of the main actors of the innovation system – including government ministries, agencies and other intermediaries, and research performers – could also be asked to formulate and implement strategic organisational plans reflecting the national strategy's orientation and objectives.
  - *Learn from the experiences of other advanced OECD countries* in developing and implementing national innovation strategies.
- *In the context of a national strategy, review FNR funding priorities and measures:*
  - *Revisit the national FNR research priorities*, as they are now eight years old and the research landscape has radically transformed over the intervening years. This should involve a deliberative process including all the main stakeholders in Luxembourg, but should be lighter and considerably shorter than the foresight exercise carried out in 2006-07. Furthermore, while selecting national FNR research priorities should take into account the industry priorities set by the Ministry of the Economy and the institutional priorities of actors like the University of Luxembourg, they should not be fully aligned simply for the sake of neatness.
  - *Translate FNR national priorities into extra support for priority areas*. In this regard, the FNR should continue with the NCER programme to develop further centres of excellence in other priority areas. Doctoral training programmes and other measures related to human resources could also be usefully aligned towards national priorities.
  - *Maintain FNR funding measures for supporting research projects that fall outside of the priority themes.* Initiatives such as the OPEN programme should become an established part of the FNR measures mix.

The Health Sciences and Technologies Action Plan

The Health Sciences and Technologies Action Plan announced by the government in mid-2008 aims to position biomedicine as a key innovation driver to foster economic diversification. The action plan originated in the Ministry of the Economy, but is a joint initiative with the Ministry of Higher Education and Research and Ministry of Health. It is notable for the significant amounts of investment made and the fact that Luxembourg previously lacked substantial research and innovation capabilities in biomedicine. At the time of its launch, the government gave multiple rationales for the initiative, including the need to improve Luxembourgish research capabilities through partnerships with leading international research centres; reduce the costs of the health system through new

therapeutic approaches; and promote economic development by creating new firms and attracting existing ones from abroad.

The government selected molecular medicine as a niche, explaining that due to its small size, Luxembourg has to specialise and be selective in its research; patents are likely in this very recent and emerging field, allowing the country to be at the cutting-edge of scientific and technological development; and developing non-invasive medical devices and technologies promises to be quicker than producing conventional drugs. While these criteria seem well chosen and compelling, the limited number of related firms and pre-existing research capabilities in Luxembourg also makes the choice of biomedicine a rather risky initiative.

At the outset, the three pillars of the action plan (commonly referred to as the "biomedical initiative") in Luxembourg were the LCSB in the University of Luxembourg (see above), the Integrated Biobank of Luxembourg (integrated into the LIH in 2015) and the Lung Cancer demonstrator project hosted at CRP Santé. While the Lung Cancer demonstrator has since been subsumed into another initiative, both the LCSB and Integrated Biobank of Luxembourg are now well-established in the Luxembourg research landscape. The biomedical initiative revolved around a strategic collaboration with several leading US institutes, which received funding to advise and train researchers working in Luxembourg, thereby providing considerable "scientific capital". The initiative's objective of improving Luxembourgish capabilities appears to be well on track. However, the partnership reportedly cost tens of millions of euros, meaning that repeating such an expensive initiative in other fields would need to be carefully considered.

The economic and health benefits of the biomedical initiative have yet to be realised. It is not realistic to expect companies to be created or attracted at a fast clip. Furthermore, scholarly research suggests that only a small share of spin-offs ever become successful, in the sense that they become small and medium-sized enterprises (SMEs) rather than large firms and are more commonly targets for acquisition by other firms. "Failures" are part of the process. Similarly, realising health benefits takes time and requires close co-operation between researchers and clinicians. Luxembourg's own historical development suggests that a reasonable amount of time should elapse before any judgement on the initiative's "success", "failure", or "effects" can realistically be made.

At the same time, while the investments and institution-building required to develop leading-edge research capabilities are a necessary condition for pursuing the diversification policy, they cannot alone guarantee success. Several framework conditions typically required for success appear to be under-developed. First, Luxembourg's industrial base and attractiveness in the biomedicine area are still low. While new infrastructures, such as the House of BioHealth at Belval, could help attract firms, the government may need to offer other incentives to entice more firms to locate in Luxembourg. Second, too little attention appears to have been paid to the regulatory framework governing health technologies, e.g. genetic testing. Innovations in the life and health sciences are generally highly sensitive to ethical, legal and regulatory frameworks. The Ministry of Health needs to take the lead in this area, but so far has played a rather minor role in the initiative. Third, a lack of tradition and history in the field means that linkages between government, industry, clinical practice and research remain weakly developed, which will likely hamper health innovation and its adoption in clinical settings.

Recommendations

- *Given the novelty of the biomedical initiative, have realistic expectations on its returns on investment*. While research should be ambitious and aim to make socio-economic contributions, it bears noting that this takes time, and many contributions from such investments are indirect and difficult to measure.
- *Urgently implement a regulatory framework conducive to biomedical innovation*, in order to exploit opportunities stemming from the biomedical initiative. For this to happen, the Ministry of Health needs to become more actively involved in the initiative.
- *Further develop clinical research in Luxembourg hospitals*, with a view to providing new treatments to local patients and – ultimately – international markets. As part of these efforts, the Ministry of Health needs to co-operate with the Ministry of Higher Education and Research to develop new professional schemes (e.g. secondments, detachments and sabbaticals) between hospitals and research centres to improve knowledge transfer and co-operation.
- *Consider launching similar – but less costly – initiatives in a few other areas*, taking into account lessons from the biomedical experience. While repeating the biomedical initiative approach for other priority areas seems unlikely due to its costs, it can provide lessons for developing a less costly and more efficient approach targeting partnerships with "excellent" or "very good" international partners. Any such initiatives should be developed in a more open and transparent manner than in the past and should involve all of the principal stakeholders.

The use of performance contracts

Following a key recommendation of the *OECD Review of Innovation Policy: Luxembourg 2007*, Luxembourg instituted a comprehensive system of steering the country's public innovation actors through performance contracts (PCs) in 2007/08. Such contracts have been concluded between the Ministry of Higher Education and Research (and other principals) on the one side and the University of Luxembourg, CRPs, the FNR and Luxinnovation on the other side. These organisations are currently into the third cycle of four-year PCs, following two cycles of three years each (though the University's cycle was always four years). The PCs state the organisation's main objectives and thematic orientations, as well as a number of carefully selected and formulated performance indicators, and the budget trajectory for the relevant period. The PCs typically also contain a *future* performance agreement. The Luxembourgish contracts also feature indicator monitoring and – less strictly – evaluations. Failure to meet indicator-based targets can lead – and has actually led – to block funding cuts, negotiated through amendments (known as "*avenants*"). Luxembourg's PC system lacks a pronounced competitive element, and organisations do not receive extra financial rewards for performing better than foreseen. The targets and indicators themselves are realistic.

Overall, this system for steering (and to a lesser degree, funding) public research actors is well-designed and has a number of advantages. First, it provides a framework for forward-looking negotiations and is well adapted to the country's small size. Second, it facilitates learning and has resulted in continuous improvements of the PCs as an instrument. Third, it addresses elements of inter-organisational collaboration. Fourth, it couples contracts with evaluation and monitoring. Overall, Luxembourg has avoided the "small-system trap", characterised by a tendency towards micro-management and the use

of too many indicators and steering instruments. The 2016-17 cycle of institutional evaluations will be an important milestone for assessing the success of the system, preferably through benchmarking with successful international comparators. The evidence so far is encouraging, though there is still scope for improvement.

Recommendations

- *Retain the amendments ("*avenants*") as an adaptation instrument but ensure process transparency.* Such an important change, effected through renegotiation, should be transparent, adequately documented and follow a clear procedure.
- *Consider rewarding "overachievers".* The current PC system rightly allows for cuts in case of underachievement, but does not foresee extra funding to reward overachievement, e.g. winning top international grants or contracts. The Ministry of Higher Education and Research should consider designing such a mechanism for the next contract period.
- *Ensure thorough and timely preparation of the 2016-17 round of evaluations at the organisational and system level.* The 2014-17 PC of the FNR presents a systematic approach to coupling strategic objectives, criteria, measurement methods and indicators to support the international evaluation with the organisation's own exercises and studies. The Ministry of Higher Education and Research should examine whether such an approach could become a standard for other organisations' PCs.
- *Embed horizontal collaboration more strongly into the PC system.* The current PCs require a common strategic plan for all research organisations. This plan features a ten-year perspective for co-operation among Luxembourg's main performers, e.g. within the CRPs and with the University. This ambitious approach has yet to be put into practice, but points in the right direction.
- *Strengthen the international dimension of future PCs.* In the past, mostly national benchmarks were used to negotiate PCs and measure performance. However, being the best in Luxembourg is not enough. Future PCs should contain more incentives and internationally oriented indicators, e.g. winning international grants and contracts (such as Horizon2020 grants and related programmes), international attractiveness and additional indicators measuring international reputation. Correspondingly, the number and weight of nationally oriented indicators should be reduced.

Horizontal co-ordination across government

The task of ensuring efficient use of increased public investment in research and innovation, and managing and addressing the needs of an expanded, more differentiated and interlinked (and more efficient) innovation system, entails a continued need for horizontal co-ordination of actors across government. This especially applies to the major ministries in charge of R&D and innovation policies – e.g. the Ministry of Higher Education and Research and the Ministry of the Economy – while the Ministry of Health plays an important role in ensuring the success of research and innovation initiatives in its area of competence (e.g. the biomedical area). Other ministries are also highly relevant to the success of innovation in Luxembourg and should be included in order to achieve a better horizontal co-ordination of policies supporting and facilitating innovation.

The Superior Committee for Research and Innovation was created in 2008 and is co-chaired by the Minister of Higher Education and Research and the Minister of the Economy. The Committee's members comprise scientists, business people and representatives of civil society, typically with international experience. The Committee was given the task of contributing to formulating and developing a coherent and effective national research and innovation policy, and advising the government on its implementation. Its impact on policy development appears to have been limited, and its actual role is rather unclear in practice; it did not gain visibility by producing reports. Nevertheless, a high-level advisory committee could fulfil a useful function if given a more clearly defined role. If retained, a reconstructed Superior Committee for Research and Innovation could be entrusted with the task of monitoring the implementation of the national innovation strategy mentioned above.

The Inter-ministerial Co-ordination Committee aiming to co-ordinate the innovation policy and related activities of the Ministry of Higher Education and Research and Ministry of the Economy, is no longer active. The Committee lost its main purpose following the creation of the PCs with the innovation agencies and public research performers. The two ministries do, however, hold regular informal meetings and co-operation seems to have improved. A new co-ordination body is emerging in the form of a committee bringing together the heads of the CRPs, the University, the FNR and representatives from the Ministry of Higher Education and Research. The purpose of the committee is to advise the Ministry of Higher Education and Research on conceiving and implementing RDI policy and related activities (the committee would complement the current Superior Committee for Research and Innovation advising both the Ministry of Higher Education and Research and the Ministry of the Economy). The committee's role is augmented by the fact that the 2014-17 PCs oblige the CRPs and the University to come up with a common ten-year strategic co-operation plan. The research organisations' move to the new Belval site should also provide an opportunity for more inter-organisational collaboration.

The recent merger of the two departments in charge of higher education and research at the Ministry of Higher Education and Research is a welcome step towards increasing permeability between the research and higher education agendas, which in turn can help improve relationships in the innovation system – including between the CRPs and the University.

Recommendations

- *Reconsider the purpose of the Superior Committee for Research and Innovation.* If retained, the Committee should have a more defined role, and its activity should be structured and linked to the strategic policy agenda. The Committee could, for example, take a key role in implementing the national innovation strategy if its organisation and *modus operandi* were revised to allow it fulfil its new role effectively.
- *Consider strengthening incentives for inter-organisational collaboration between CRPs and the University in the next generation of PCs,* depending on the experience in the current round.

Fostering innovation in the business sector

Luxembourg is primarily a service economy, endowed with a strong financial services sector. SMEs account for the lion's share of value added and employment in the business sector. Their dominance is even greater than average in the European Union,

partly reflecting the high-value activities of small businesses linked to the financial sector and ancillary activities. Indigenous businesses are generally small.

Thanks to its geographic position, generally favourable framework conditions and proactive investment support (including through business regulation), Luxembourg is an attractive location for foreign investment. Many MNEs choose to locate parts of their global operations in Luxembourg, including headquarters, through holding companies. The tyre manufacturer Goodyear Luxembourg and materials manufacturer DuPont de Nemours are two examples of innovative MNEs with production sites in Luxembourg. Other MNEs with substantial operations in Luxembourg include steel manufacturer ArcelorMittal and international financial services firm Dexia. Major media companies (e.g. SES Global, SES Astra, Skype Technologies and RTL Group) also have their headquarters and part of their operations in Luxembourg. The country is also an important logistics hub.

Available evidence points to several innovation strengths. Evidence from the EU Community Innovation Survey suggests that a high share of Luxembourgish firms have introduced product, process, marketing or organisational innovations in recent years. A relatively high number also engage in multiple innovation modes (e.g. product and process, as well as marketing and organisational innovation). Nevertheless, business R&D expenditure is relatively low, and has declined over time.

The 2009 Law for the Promotion of Research, Development and Innovation – which updated and replaced the former 1993 Law on State Aid for Research, Development and Innovation – provides the legislative framework for public support of R&D and innovation in the business sector. The Law defines financial support for business innovation, which takes place through direct funding of R&D and innovation projects (approved grants amounted to EUR 30-40 million a year in 2011-12 and exceptionally up to EUR 75 million in 2013), collaborative projects with the CRPs and University of Luxembourg (about EUR 1 million in 2010, increased to almost EUR 9 million in 2013) and funding for process and organisational innovation in services (about EUR 3 million). The eligibility criteria match EU rules and include provisions for directing higher shares of co-funding to projects involving SMEs, fundamental research and cross-border collaboration. A number of specific programmes target SMEs and young innovative enterprises; the remaining interventions are meant to provide the institutional – and in some cases physical – infrastructure that can foster business-innovation capabilities. They take the form of support for clusters, incubators and business parks; innovation contests and awards; technology matchmaking; and advice on IP rights management. With the exception of Luxinnovation's sizeable budget (about EUR 11 million per year), they are much less resource-intensive.

The 2009 Law provided for new possibilities to develop policy measures that appear to have helped rebalance the policy mix. At the same time, several aspects of instrument design and implementation could be improved. First, the existing policy framework to promote innovation in the business sector lacks a clear strategic orientation and is lacking explicit rationales explaining the choice of specific instruments and the magnitude of the budgets. The instruments are not always aligned with government priorities (e.g. the sectoral action plans) and strategic goals: most of the programmes are open to all kinds of R&D and do not target specific sectors. The only exception is the Luxembourg Cluster Initiative, which mainly provides business-support services rather than implementing ambitious innovation projects. While neutral innovation support is certainly helpful to promote innovation in all sectors, a stronger alignment between business-innovation

programmes and national priorities could foster synergies between public research and business innovation and upgrade the business sector's absorptive capacity.

Furthermore, strengthening business-innovation performance in both existing and new companies requires using innovation policy instruments in ways that facilitate accumulating in-house innovation capabilities and progressively extending their ambition. Transitioning to a rigorous evaluation and selection of project proposals based on their commercial viability, as well as scientific and technological merit, would help induce behaviour that would not exist in the absence of policy. However, this transition would require increased administrative resources and capabilities, and may be difficult to bring about within current institutional arrangements. Delegating some implementation functions (notably funding) to an agency outside of the Ministry of the Economy would result in a division of labour, possibly leading to more sophisticated programming and implementation – as is already the case in many countries with advanced innovation systems.

Last but not least, the growing resources and increasing maturity of the system, together with the ambition to use innovation policy as an economic diversification tool, call for changes in the programming and delivery of innovation policy. Linking government intervention to specific instruments and (to the extent possible) measurable objectives can enhance the legitimacy of innovation policy and provide a common framework for discussion and policy development. While the existing policy mix is helpful to many firms, the lack of policy-impact evaluations makes it difficult to ascertain to what extent it is a good use of public resources. In countries with a long history of innovation policy (e.g. the Netherlands), programming and instrument design is typically informed by past evaluations and adjusted to evolving policy challenges. Ensuring the long-term efficiency and effectiveness of innovation policy would require introducing similar processes in Luxembourg. The imminent revision of the 2009 Law would provide a good opportunity for evaluation, possibly performed by mixed national and international expert teams.

Recommendations

As the innovation system matures and ambition and funding levels increase, business-innovation policy will need to become more discerning and target behavioural changes (e.g. to accumulate innovation capabilities, foster collaboration with the public research system and raise ambition). This highlights the need to:

- *Consider aligning some of the instruments promoting business-sector innovation as national sectoral and research priorities.* This would facilitate creating research and innovation P/PPs and further diversifying the national diversification strategy.
- *Make business R&D support more competitive and selective* and consider instituting competitive funding for larger, more strategic or collaborative projects in addition to a generic R&D funding instrument with low barriers. This would require applying a rigorous R&D project-appraisal process to select the best projects based on their scientific, technological and commercial potential.
- *Consider delegating some business-innovation policy implementation functions – notably project selection and funding – to benefit from professionalised agencies.* Possible scenarios include extending the capabilities and raising the ambition of Luxinnovation (in the same vein as the Finnish Tekes, collaborating with the FNR where required) or a possible delegation to the FNR and corresponding extension of its capabilities (like the Research Council of Norway).

- *Routinely evaluate programmes and instruments supporting business*. Evaluation can improve the effectiveness and efficiency of innovation policy, particularly with respect to longer-term goals (e.g. economic diversification and capability accumulation). Evaluating current innovation programmes would help strengthen the evidence base for future amendments of legislation on R&D and innovation, feeding back into policy design. Making evaluations public would create awareness and facilitate learning in the wider system.

Supporting international knowledge linkages

Like other advanced small OECD countries, Luxembourg has established strong international linkages that are also reflected in relevant STI indicators. Luxembourg's high degree of STI-related internationalisation is reflected in (among others) bibliometric indicators: over 70% of its top-cited scientific publications – the highest share among OECD countries – involve a foreign co-author. This owes in part to well-established collaborations, notably with neighbouring countries, and a high share of foreign R&D personnel: in 2003, almost 40% of internationally co-authored publications had a co-author from France, Germany or Belgium. This share decreased to 32% in 2012, mostly due to an increase in co-authorship with researchers from the United Kingdom and the United States.

Luxembourg's participation in the EU Framework Programme is low compared to leading European countries, where advanced small-sized economies tend to attract higher amounts of European funding per researcher. A small share of Luxembourgish Framework Programme participants (14%, compared with 28% in the United Kingdom, 20% in the Netherlands and 18% in Denmark and Belgium) played a co-ordinating role. As happens with scientific co-authorship, Luxembourg mainly collaborates on EU projects with organisations in neighbouring countries.

Over time, Luxembourg has strengthened its membership in European agencies and consortia (such as the European Space Agency, European Molecular Biology Laboratory or EUREKA). Luxinnovation acts as the official National Contact Point for EU research and innovation programmes and actively supports (private and public) research organisations in preparing applications. However, a 2010 evaluation of Luxinnovation shows that CRPs considered its technical support too generic to provide real value added to researchers. The same evaluation showed that the relatively low participation in European programmes is also explained by their more competitive nature compared with national funds, both for enterprises and researchers. Although the evaluation dates back to 2010 and Luxembourg's participation in EU programmes has improved since then, there is still considerable room for improvement.

FNR programmes cover multiple aspects related to the internationalisation of public research, including mobility programmes to recruit foreign senior and junior researchers and give Luxembourgish researchers the opportunity to spend part of their career abroad. The budgets allocated to this purpose are not entirely spent, yet another proof that attracting talent remains a challenge. At the same time, the current success of the two interdisciplinary centres at the University of Luxembourg owes much to the attraction of high-calibre researchers. Moreover, since the late 2000s, the FNR has signed bilateral and multilateral agreements with research funding agencies in leading European countries, including the United Kingdom, Germany and Switzerland. Additional agreements with partners in Europe and beyond are currently under negotiation.

A number of cross-border initiatives promoting science-and-innovation linkages within the Grande Région have been developed recently, including: i) the Université de la Grande

Région, an inter-university consortium comprising six universities in the cross-border area; ii) cross-border clusters, notably in the field of material sciences; and iii) business-support activities, e.g. matchmaking or networking events. Successful collaborations in science and research depend on finding the most suitable partners, irrespective of their location. However, for other types of collaboration (e.g. involving business development agencies, clusters, SMEs or services that need to be delivered by local actors, including undergraduate higher education), critical mass, agglomeration and proximity are decisive. The Grande Région is the suitable place for this type of policy intervention.

Recommendations

- Given its small size, Luxembourg compares particularly favourably on STI indicators related to internationalisation. However, *the quality and ambition of these international collaborations should be carefully assessed through both quantitative and qualitative STI indicators* to gain a better understanding of the nature of international partners, their location (e.g. proximate vs. global collaboration) and the (leading or supporting) role played by Luxembourgish actors. Policy promoting STI internationalisation should be designed and targeted accordingly.
- *Prioritise improving participation in, and the range of benefits derived from, European research programmes.*
  - *Consider establishing a common Office of Advisors* (serving both the University of Luxembourg and the CRPs) to assist researchers in building project consortia and drafting Horizon2020 research proposals.
  - *Improve co-ordination between Luxinnovation and the FNR.* Providing assistance to research-intensive actors, including both public and private organisations, would also help.
- *Continue the effort of the FNR to expand bilateral partnerships* as part of its internationalisation strategy, with a view to extending them to developed and emerging economies beyond Europe.
- *Focus research and innovation efforts targeting the Grande Région on areas where collaboration most benefits from critical mass and agglomeration,* e.g. physical research infrastructure (including access to laboratories or libraries), business coaching, job placement initiatives and support for technology transfer and incubators. The University could also consider jointly providing undergraduate courses with higher education institutions in the region in fields where it struggles to achieve critical mass.

Note

1. For many purposes, gross national income per head may be seen as a more relevant indicator for a (very) small open economy such as Luxembourg.

Chapter 2.

Economic and innovation performance in Luxembourg

This chapter discusses Luxembourg's macroeconomic performance. The first section presents salient features of the Luxembourg economy – such as its openness to international trade and investment, and the important role of services – (especially financial services) – and sketches patterns of structural change in production and trade. It also looks at the current state of framework conditions as they relate to entrepreneurship and innovation. It concludes with a brief discussion of the role of innovation in the country's longer-term economic development. The second section reviews Luxembourg's aggregate innovation performance relative to other OECD countries with comparable levels of innovation system development, size and geographical proximity. It starts by examining expenditure across institutional sectors (business, higher education and government) and considers the human resources for innovation. It then reviews indicators of innovation output (drawn from bibliometric and patent data) to highlight some qualitative characteristics of Luxembourg's innovation system.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Contributing to the great effort to overcome a long history of conflict on the European continent, Luxembourg has consistently played an active role in Europe's political and economic integration. As a founding member of the Benelux group of countries, it has to this day helped advance and operate the institutions that constitute the European Union and the Economic and Monetary Union. The city of Luxembourg is the seat of several European institutions and agencies, including the European Court of Justice, the European Court of Auditors and the Statistical Office of the European Communities (Eurostat). It also hosts the European Commission's Directorate-General for Translation, as well as the Secretariat of the European Parliament. Luxembourg naturally participates in the Schengen group of countries, named after the Luxembourger village of Schengen where the agreement facilitating free movement of citizens among member states was signed.

Luxembourg is one of the most prosperous countries in the world. It owes its economic success to a high degree of resilience and versatility, having succeeded in profoundly restructuring its economy twice over the last century. During the last decades of the 20th century, Luxembourg rapidly and deeply specialised in fast-growing, high value-added service activities, notably financial and related services. As a result, the country transformed from a heavily steel-based economy to a major international financial centre, supported by the liberalisation of the financial sector and early adoption of a number of European Union (EU) financial services directives. Luxembourg has also built strengths in related business services, including legal and information and communications services as well as transport and logistics (air cargo), making use of its favourable geographical location. The manufacturing base is relatively small, but includes a number of partly international innovative enterprises. The global financial crisis has triggered debate on the future viability of established growth models.

2.1 Macroeconomic developments

Macroeconomic performance before and after the crisis

Luxembourg's gross domestic product (GDP) per capita is USD 90 724 (US dollars, 2013, current prices and purchasing power parity [PPP]) – the highest in the OECD area and among the highest in the world. International comparisons based on GDP per capita call for some caution, however, given Luxembourg's specificities as a (very) small and highly internationally oriented economy. While differences between GDP and gross national income (GNI) tend to be rather small for most countries, GNI is about one-third lower than GDP in Luxembourg, where non-residents contribute a large share of the economy's labour or capital.[1] However, even in terms of GNI (as opposed to GDP) per head, Luxembourg still holds a top position in the OECD area, second only to Norway, ahead of the United States and Switzerland, and way above the EU and OECD averages (OECD, 2015, Annex 3). Luxembourg's success is not limited to economic performance measures. Taking a broader perspective, the country also surpasses – or at minimum achieves – the OECD average in most dimensions of the OECD Well-Being Index (OECD, 2015a).[2]

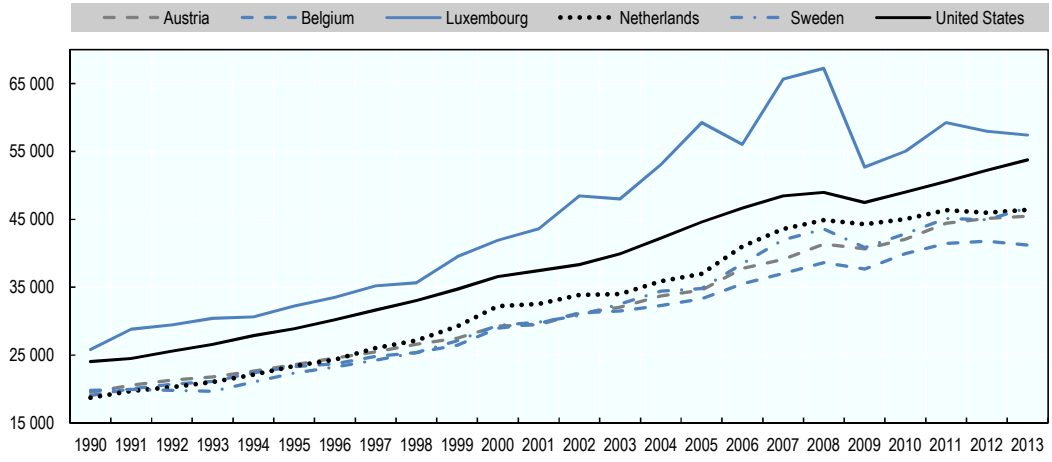
Very high levels of output and income per capita reflect Luxembourg's solid past economic performance. Viewed over the long term, Luxembourg records strong and robust economic growth, and comparatively low levels of unemployment and inflation. The most recent *OECD Economic Survey: Luxembourg* (OECD, 2015a) shows that the Luxembourg economy grew twice as fast as the European average in the two decades before the global financial and economic crisis that hit the country in 2009. GDP per capita was already high in the 1970s, but still below the Swiss level until well into the

1980s, when Luxembourg embarked on a unprecedented growth acceleration, far outpacing other well-performing comparator countries such as Austria, Belgium, the Netherlands and Sweden. GNI per head also grew faster than in comparator countries and peaked before the onset of the crisis (Figure 2.1).

Luxembourg's outstanding aggregate economic performance in recent decades rested on a massive shift in economic specialisation from steel towards financial and related services. The extraordinary degree of specialisation in financial services that has resulted from this restructuring has served as an engine of Luxembourg's economic growth in recent decades, but also has downsides.

Figure 2.1. **Medium-term economic performance**

GNI per capita in international USD (PPP) for selected OECD countries, 1990-2013



Note: GNI per capita, USD, current prices, current PPP.

Source: World Bank (2015), *World Development Indicators* (database), http://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD.

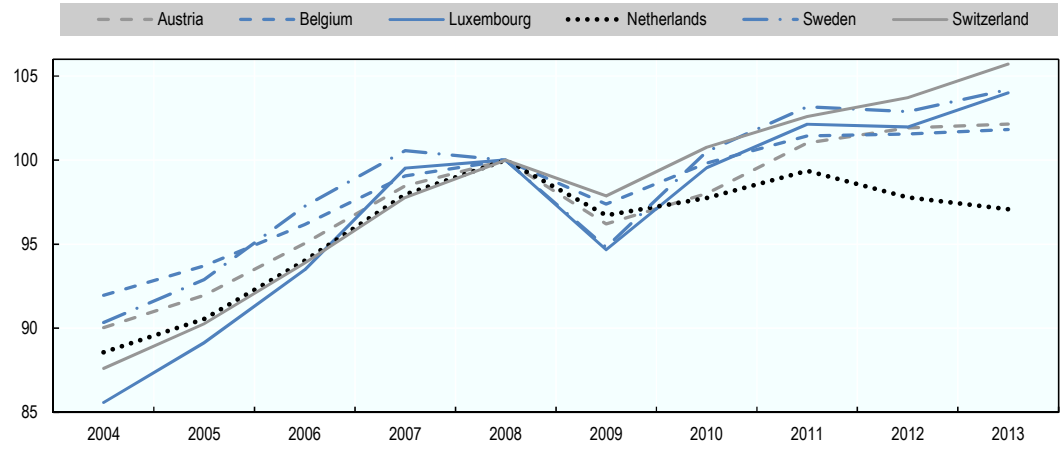
During the global financial and economic crisis in the second half of the 2000s, Luxembourg's economic output contracted sharply by about 5.5%, more deeply than in comparable European economies (Figure 2.2). The economy rebounded quickly, however. Overall, Luxembourg clearly weathered the crisis better than most economies in the euro area. From 2008 to 2013, its real GDP per capita grew as much as Sweden's, and faster than that of Austria and Belgium, two countries which – in contrast to the Netherlands – also succeeded in avoiding a prolonged double-dip recession. Among comparator countries, only Switzerland performed better than Luxembourg in the aftermath of the crisis. Thus, Luxembourg's current macroeconomic situation remains favourable overall, and its public finances are among the most solid. Thanks to its sustained services exports (mainly of financial services) Luxembourg's current account surplus is still in the range of 5% of GDP (down from 10% prior to the crisis).

The crisis had a different impact across sectors, however (see OECD, 2015a): the upward trend in financial sector value-added ended, and was even to some extent reversed (Figure 2.3). The diversification that took place within the financial sector helped contain its contraction. Manufacturing output was harder hit, declining by about one-third since 2007. The value-added of professional, scientific and technical activities also shrank, albeit far less dramatically than for manufacturing. Remarkably, the

expansion of value-added of the information and communications technology (ICT) sector continued and even accelerated after 2009.

Figure 2.2. **Economic performance before and after the crisis**

Real GDP for selected countries, 2004-13

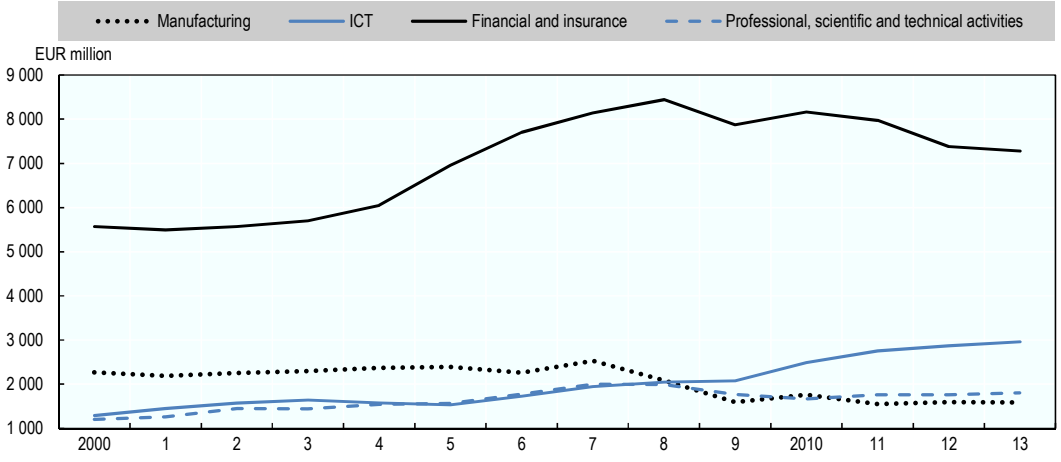


Note: Real GDP at constant prices, 2008 =100.

Source: OECD (2015b), *National Accounts* (database), http://dotstat.oecd.org.

Figure 2.3. **Sectoral output divergence in the wake of the crisis**

Real value-added, at constant prices, reference year = 2005



Source: OECD (2015a), *OECD Economic Surveys: Luxembourg 2015*, http://dx.doi.org/10.1787/eco_surveys-lux-2015-en, based on STATEC.

In the short term, GDP growth is projected to lose some momentum (2.2% in 2015) as the EU value added tax (VAT) regime for e-commerce shifts from the seller to the buyer country and (the so far comparatively low) VAT rates increase in Luxembourg (OECD, 2014a; OECD, 2015a). GDP growth is expected to accelerate somewhat in 2016 (2.6%) in a sluggish international economic environment and notably in the euro area, where downside risks remain. However, Luxembourg's growth is expected to remain significantly above the euro area average.

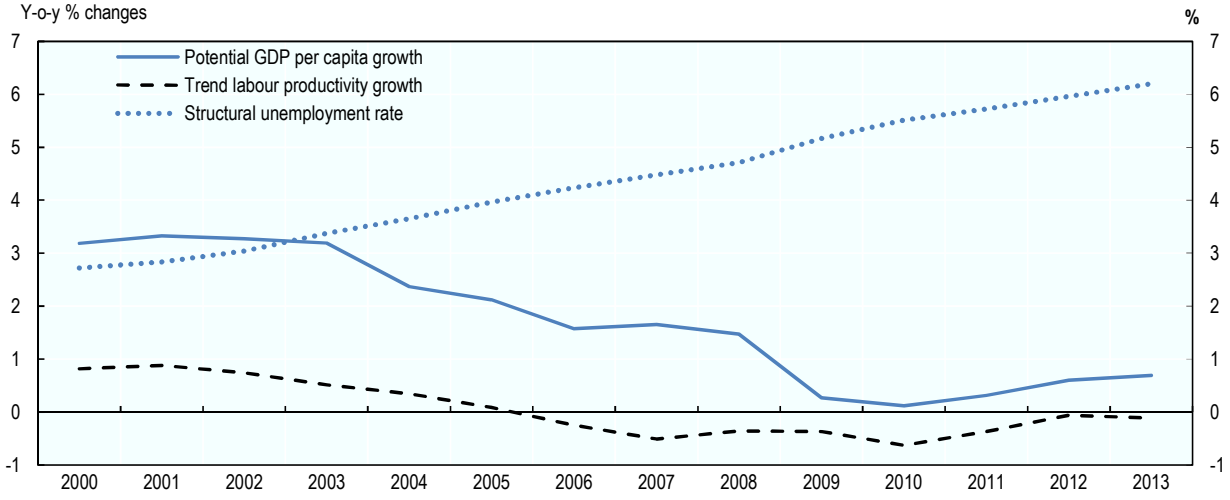
Challenges

Luxembourg's economy performed very well prior to the onset of the crisis and managed its fallout rather well by international standards. Nevertheless, it faces significant challenges, including reducing unemployment, strengthening productivity growth and diversifying the economy.

The unemployment rate reached 7%, and the share of the long-term unemployed (for a year or more) has risen to more than 25% of total unemployment.[3] Given these trends, reducing unemployment – especially among lower-skilled resident workers – is an important challenge, including for education and training institutions.

A major challenge for Luxembourg is to achieve and maintain adequate productivity growth in the long term. Productivity is commonly recognised as a main driver of long-term economic growth and the major source of differences in GDP per capita across countries (OECD, 2013a). While Luxembourg's levels of labour productivity are very high, recent OECD estimates indicate that trend labour productivity growth has declined after early 2002 and was already negative before the onset of the crisis. Together with the rising structural unemployment mentioned above, this has contributed to a slowdown of Luxembourg's potential per capita output growth (Figure 2.4).[4]

Figure 2.4. **Trend in unemployment and productivity**



Source: OECD (2015a), *OECD Economic Surveys: Luxembourg 2015*, http://dx.doi.org/10.1787/eco_surveys-lux-2015-en, based on OECD (2014a), *OECD Economic Outlook*, http://dx.doi.org/10.1787/16097408.

A third long-term challenge for Luxembourg is reducing the economy's strong dependence on the financial sector, which has underpinned much of its growth of recent decades. Not only does recent empirical work indicate that overspecialisation in financial activity may exert a drag on growth (OECD, 2015a), it may also entail vulnerabilities, as became evident in numerous countries during the crisis. The crisis and its aftermath have triggered changes in the international environment that in turn have induced adaptations of the financial sector's operating framework, possibly resulting in a restructuring or shrinking of the sector. Luxembourg has been losing some advantages, e.g. related to international information exchange and the favourable fiscal treatment of international

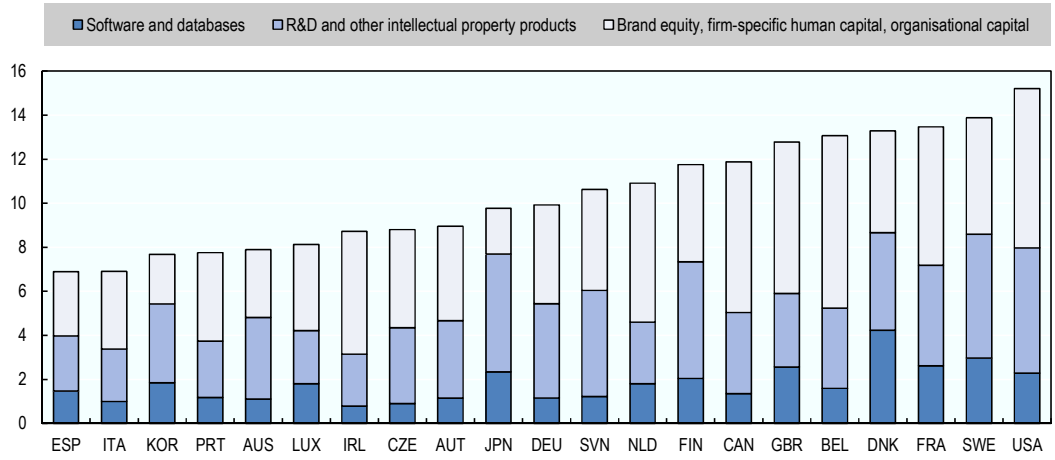
businesses domiciled in the country. As a consequence, the financial sector might lose some importance as a source and driver of future economic growth.

The central role of productivity in driving long-term growth deserves additional attention. Labour productivity growth is driven by increases in capital intensity and multifactor productivity (MFP), which indicates the joint efficiency of production inputs, labour and capital. Evidence shows that MFP is more important than capital intensity in explaining cross-country income differences (see, for example, Hall and Jones, 1999; Inklaar and Timmer, 2009; and Johansson et al., 2013). In advanced economies operating close to the technological frontier, continued long-term growth typically relies on improvements in MFP, which in turn depends on a swift reallocation of resources towards innovative firms. Recent work (summarised in OECD, 2013b) highlights the role of innovation and investment in knowledge-based capital (KBC) – e.g. assets that lack physical embodiment, such as computerised information, intellectual property and economic competencies – which has been identified as an important contemporary driver of productivity and growth, especially in advanced economies (Corrado et al., 2012). In Luxembourg, investment in KBC as a percentage of the business sector's value-added is lower than in other OECD countries (Figure 2.5). This gap is partly explained by comparatively low levels of expenditure on research and development (R&D), but investment in other types of knowledge-based assets is also lagging in relative terms. Hence, fostering investment in KBC and strengthening innovation capabilities seems a promising way of contributing to Luxembourg's economic diversification (both within and across sectors) to further upgrade its position in global value chain, and raise productivity (OECD, 2015a).

According to results of recent productivity research (e.g. the LuxKlems Project 2012, reported in Observatoire de la compétitivité, 2013), Luxembourg's MFP before the crisis developed in a similar vein to France, Belgium and the United States, characterised by an efficient use of inputs and positive rates of technical change. In the wake of the crisis, however, "Luxembourg experienced some efficiency losses, which displaced the efficient frontier, and technical regress" (Observatoire de la compétitivité, 2013).

Figure 2.5. **Investment in KBC**

As a percentage of value-added of the business sector



Source: OECD (2013c), *Science, Technology and Industry Scoreboard*, http:/dx.doi.org/10.1787/sti_scoreboard-2013-en.

2.2 Framework conditions for innovation and entrepreneurship

The role of framework conditions

The macroeconomic and general business environment, product and labour market regulations, competition intensity, the accessibility and quality of business financing, the level and quality of entrepreneurship, the tax system and the quality of infrastructure all influence a country's innovation performance. Good framework conditions stimulate firms to engage in innovation and R&D, and support the diffusion of innovations throughout the economy and society at large. Thus, conducive framework conditions and a healthy business environment are key prerequisites for strong innovation performance of individual innovation actors and the innovation system as a whole. Moreover, framework conditions for innovation have gained importance in recent decades as businesses and capital have become more mobile and select the most favourable operating environments. Framework conditions are important for several reasons:

- Innovation activity requires a medium- or long-term horizon and a sufficiently stable operating environment. This is particularly important for R&D, as well as more fundamental and costly types of innovation activity.
- The regulatory framework is crucial to generating and speeding the diffusion of new technologies. A favourable regulatory framework critically accelerates the reallocation of labour and capital to innovative firms and industries which in turn stimulates investment in KBC by raising its return (Andrews and Criscuolo, 2013).
- Vigorous competitive pressure provides a powerful incentive for business innovation. By contrast, a lack of competition allows inefficient firms and technologies to remain in the market.
- When framework conditions are deficient, they are likely to reduce the effectiveness of policies designed to foster innovation.

Favourable framework conditions facilitate innovation throughout the economy. At the same time, the OECD experience shows that "dedicated" policy measures are also needed to address specific market or systemic failures that hamper R&D and innovation. Empirical OECD work has found that both framework conditions and dedicated science, technology and innovation (STI) policies affect innovation performance, both separately and in combination; it has helped identify the policies, institutions and framework conditions that support innovation effectively (Jaumotte and Pain, 2005a, 2005b; Westmore, 2013).

Overall, the first OECD review of Luxembourg's innovation policy (OECD, 2007) found that Luxembourg offers researchers and innovators the advantages of a central geographic location and overall favourable framework conditions, such as a stable macroeconomic environment, a reliable legal framework and a developed financial system. The review also highlighted the importance of an ongoing fine tuning of framework conditions and co-ordination of relevant policies. Overall, these findings still hold true today. Framework conditions for innovation and entrepreneurship in Luxembourg are largely supportive and have contributed to a good economic performance. In many respects, Luxembourg is an attractive business location thanks to its regulatory and tax systems, its sound macroeconomic policies and openness to international trade, foreign investment and skilled workers from other countries. The

country does, however, have scope for improvement in some areas (OECD, 2007). Some barriers seem to be related to human resources and labour markets.

Section 2.1 discussed broad macroeconomic conditions. This section considers the broad features of entrepreneurial activity and key framework conditions that support innovation in the areas of international trade and investment, product and labour market regulation, risk finance and infrastructure.

International openness

In addition to general macroeconomic conditions, openness to trade and integration into capital and goods markets are essential to an innovation-friendly environment. By providing better opportunities for growth, trade openness may lead to economies of scale and encourage innovation through stronger competition. Cross-border investments stimulate innovation, which fosters knowledge transfer from abroad and contributes to diffusing innovative management practices. In a small open economy in particular, foreign trade and foreign direct investment (FDI) flows are critical to economic growth and development (Keller, 2002).

Luxembourg is one of the most open economies in the world. It owes this position to its size, its appurtenance to the Benelux area (comprising Belgium, the Netherlands and Luxembourg), its geographic location between France and Germany (the two largest economies of the euro area) and proximity to a densely populated, highly developed area of Western Europe, as well as aspects of its regulatory and tax regime. The prevalence of multilingualism in the country has helped build its international orientation. Economic activity goes much beyond the confines of a very small domestic economy. Luxembourg plays a key role as a financial centre and is arguably the most open OECD country, integrated into the international economy through trade and foreign investment flows. Approximately 163 400 (2013) daily commuters (around one third of the country's total population) come to work in Luxembourg from neighbouring countries (Belgium, France and Germany).

Luxembourg leads OECD countries in international trade, which stood at 143.6% (measured as the average of imports and exports of goods and services over GDP) in 2012 – exceeding Ireland, the follow-up, by no less than 50 percentage points. Among the most open economies are the two other Benelux countries, Belgium and the Netherlands, as well as some central and eastern European countries. In contrast to most other countries, Luxembourg largely owes its top position to international trade in services, aided by its favourable framework conditions. The scores on the OECD Services Trade Restrictiveness Index indicate that Luxembourg is below (e.g. less restrictive than) the OECD average in 16 out of 17 sectors (OECD, 2015a).

Today, integration into the global economy is increasingly taking place through global value chains (GVCs). Recent OECD work (OECD, 2014b) provides a basis for characterising a country's trade integration in terms of specialisation within GVCs (e.g. Luxembourg's specialisation in the automobile-related GVC). As could be expected, trade in value-added statistics indicate that Luxembourg relies heavily on imported intermediaries and, conversely, that the domestic value-added content of exports is small. The share of domestic value-added in gross exports is indeed the lowest among OECD countries (just above 40%, according to data for 2009). A characteristic of Luxembourg is that the share of services value-added in its total exports exceeds 80%. The recent *Economic Survey: Luxembourg* (OECD, 2015a) shows that the country's integration of financial services in GVCs is the highest among OECD countries. However, integration is

considerably lower in other knowledge-intensive services, such as transportation and telecommunications. The *Economic Survey* suggests this may indicate some unexploited potential to raise productivity by further integrating higher value-added non-financial activities, including business services, into GVCs.

In addition to being very open to international trade, Luxembourg is also highly open to international investment. The outward and inward FDI stock, as a fraction of GDP, is the highest among OECD countries, ahead of Belgium, Ireland, Switzerland and the Netherlands. However, it bears noting that these numbers are heavily influenced by the choice of location, not only for production, but also for headquarters and special financial institutions.

Foreign-owned firms' local economic activities can affect a country's innovation performance, both directly and indirectly. They can boost host countries' productivity, because firms receiving FDI often gain in efficiency through technology transfer, better organisation and management practices, qualified human resources, or better integration in international markets and GVCs. Knowledge spillovers from FDI firms may also lead to efficiency improvements in the wider population of domestic firms. These gains may occur in the same sector, in upstream or downstream firms (suppliers or customers), or in regional innovation networks involving foreign-controlled firms. These spillovers critically depend on the absorptive capacities of local firms – which, however, hinge on their innovation capabilities. FDI can also stimulate innovation indirectly, e.g. through increased competition.

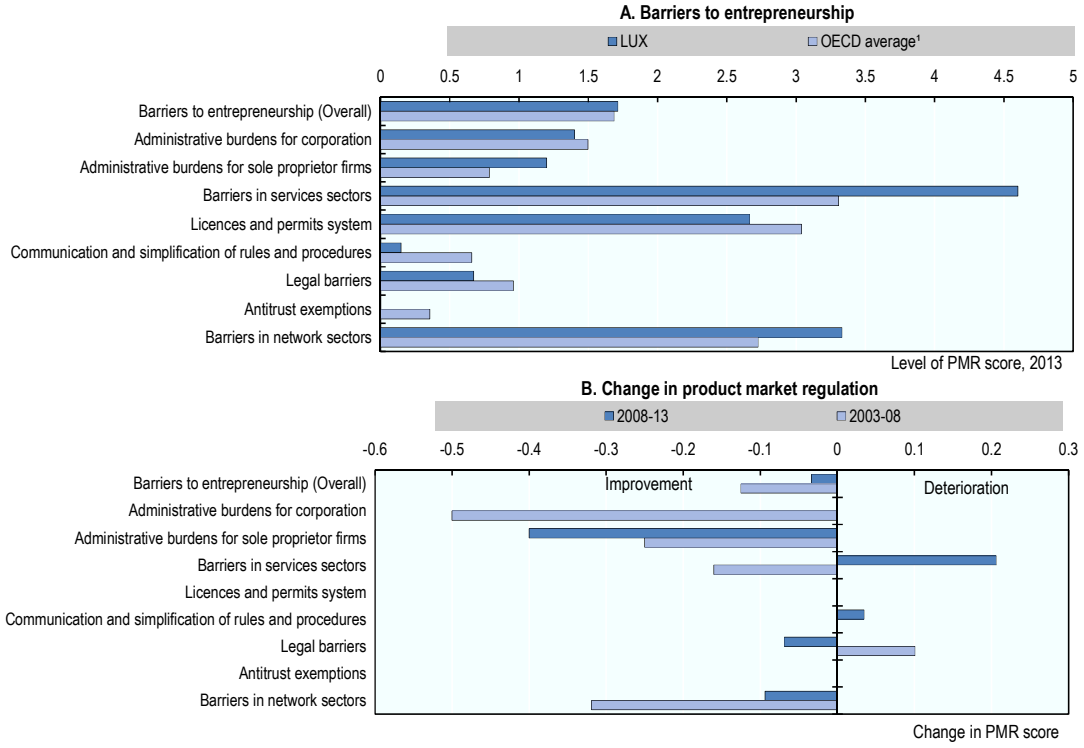
The business environment affecting entrepreneurship

The business environment strongly influences entrepreneurship and productivity. Product market regulation (PMR) in particular affects productivity performance. Lower entry barriers foster competition, which in turn provides powerful incentives for firms to innovate and stimulates knowledge diffusion (Westmore, 2013). Less-restrictive regulations also allow firms to obtain the range of resources they need to undertake their innovative projects and grow.

Luxembourg has strengthened its business environment over time. Figure 2.6 shows its evolution in terms of the "barriers to entrepreneurship" dimension of the OECD PMR Index and its components (Koske et al., 2015; see Box 2.1 below). Overall, barriers to entrepreneurship were eased between 2003 and 2013, including by lowering the administrative burdens of sole proprietors, as well as barriers in the network sectors – although the government retains full ownership of the major telecommunication network operators (Luxconnect and Enterprise des postes et télécommunications). Some exceptions do exist, however: barriers in services sectors have increased (owing to tighter regulation in retail trade licensing) and little progress has been made in ensuring that regulation in professional services is more competition-friendly (OECD, 2015a). Further, despite the improvements mentioned above, barriers to entrepreneurship still remain higher than in the best OECD performers.

Luxembourg's employment protection legislation is more restrictive than the OECD area average (Figure 2.7). In fact, the *Global Competitiveness Report* (World Economic Forum, 2013) ranks restrictive labour regulations as the most problematic factor for doing business (see Figure 2.8): 22.7% of respondents cite restrictive labour regulations and 18.6% cite an inadequately educated workforce; 12% cite an inefficient government bureaucracy (12.0%). Access to financing (11.0%) also plays a role, but appears much less prominent than in other countries (including close neighbours such as the Netherlands).

Figure 2.6. **PMR: Barriers to entrepreneurship**



Note: All indices below the first line are sub-indices of the index "Barriers to entrepreneurship".

1. Simple average of OECD countries, 2013 data; latest US data is 2008.

Source: OECD (2015a), *OECD Economic Surveys: Luxembourg 2015*, http://dx.doi.org/10.1787/eco_surveys-lux-2015-en, based on the OECD PMR database, 2013 edition.

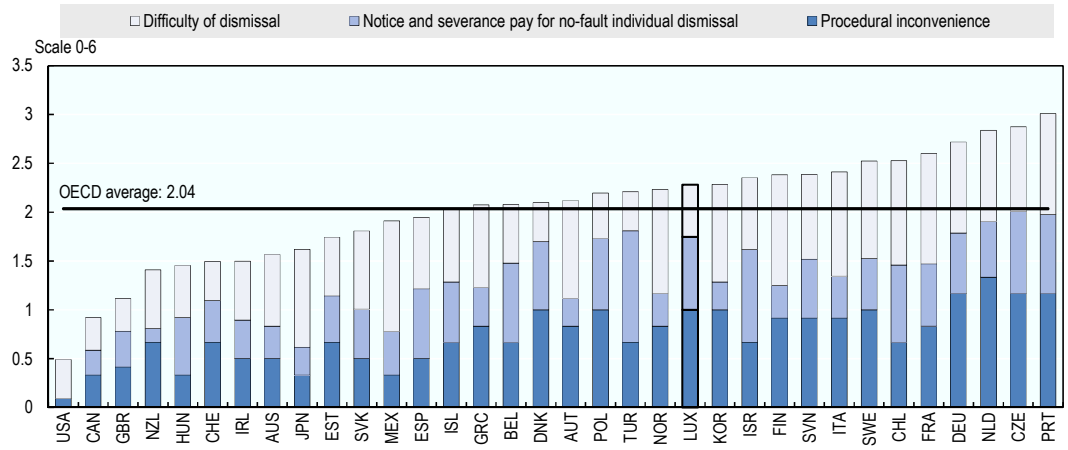
For economies to thrive on innovation, labour and other resources need to be continuously reallocated within and across firms and sectors. Stringent employment protection hinders the redirection of resources towards their most productive uses and hence productivity growth. It tends to reduce R&D expenditure (Andrews and Criscuolo, 2013), hampering firms engaging in innovations and needing skilled personnel and complementary resources to implement and commercialise them.

Venture capital

Financial conditions are critical to firms' ability to obtain the resources they require. This is especially critical for young and small businesses, which tend to be more constrained by a lack of available internal funding or collateral. Some of these businesses play an important role as a source of innovative business models and radical innovations (Andrews and Criscuolo, 2013). Well-functioning financial markets help them grow and expand the scale and scope of their innovation activities. An environment in which it is easier for successful firms to upscale also creates better opportunities to innovate and experiment with new solutions.

Figure 2.7. **Strictness of employment protection legislation**

Scale from 0 (least stringent) to 6 (most restrictive), 2013

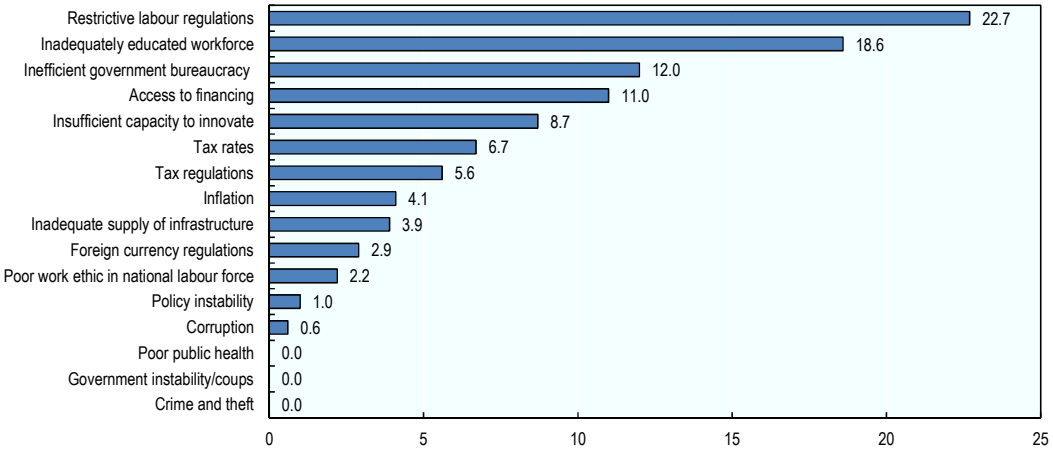


Notes: The figure presents the contribution of different subcomponents of the indicator for employment protection for regular workers against individual dismissal (EPR). The EPR incorporates three aspects of protection: i) procedural inconveniences that employers face when starting the dismissal process, such as notification and consultation requirements; ii) notice periods and severance pay, which typically vary by employee tenure; and iii) difficulty of dismissal, as determined by the circumstances in which it is possible to dismiss workers, as well as the repercussions for the employer (such as compensation and reinstatement) if a dismissal is found to be unfair. The height of the bar represents the value of the EPR indicator.

Source: OECD (2013d), *OECD Employment Outlook 2013*, http:/dx.doi.org/10.1787/empl_outlook-2014-en.

Figure 2.8. **The most problematic factors for doing business**

Percentage of respondents



Note: From the list of factors above, respondents were asked to select the five most problematic for doing business in their country and to rank them between 1 (most problematic) and 5 (least problematic). The bars in the figure show the responses weighted according to their rankings.

Source: World Economic Forum (2013), *The Global Competitiveness Report*, http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2013-14.pdf.

Box 2.1. **The OECD PMR indicator**

A number of diagnostic tools have been developed to measure PMR and benchmark regulatory frameworks. One of these tools is the OECD product market indicator system. The PMR indicators assess the extent to which the regulatory environment promotes or inhibits competition in markets where technology and market conditions make competition viable. These indicators have been used extensively over the last decade to benchmark regulatory frameworks in OECD and other countries, and have proven useful in encouraging countries to implement structural reforms that enhance economic performance.

The PMR indicator system summarises a large number of formal rules and regulations with a bearing on competition. The regulatory data cover most of the important aspects of general regulatory practice, as well as a range of features of industry-specific regulatory policy, particularly in the network sectors and more recently in the area of regulating the Internet economy. This regulatory information feeds into a set of low-level indicators that form the base of the PMR indicator system. These low-level indicators are then aggregated. At the top of the structure, the overall PMR indicator serves as a summary statistic on the general stance of product market regulation.

The PMR indicators have a number of characteristics that differentiate them from other indicators of the business environment. First, in principle, the low-level indicators only record "objective" information about rules and regulations, as opposed to "subjective" assessments of market participants, as in the case of indicators based on opinion surveys. This isolates the indicators from context-specific assessments and makes them comparable across time and countries. Second, the PMR indicators follow a bottom-up approach, in which indicator values can be related to specific underlying policies. One of the advantages of this system is that the values of higher-level indicators can be traced with an increasing degree of detail to the values of the more disaggregated indicators and, eventually, to specific data points in the regulation database. This is not possible with indicator systems based on opinion surveys, which can identify perceived areas of policy weakness, but are less able to relate these to specific policy settings.

Source: Wölfl et al. (2009), "Ten Years of Product Market Reform in OECD Countries: Insights from a Revised PMR Indicator"; Koske et al. (2015), "The 2013 Update of the OECD's Database on Product Market Regulation: Policy Insights for OECD and non-OECD Countries".

Venture capital is a particularly salient form of private equity financing (e.g. equity capital provided to firms not quoted on the stock market) for young companies with innovation and growth potential, replacing or complementing traditional bank finance. It is an important element of an innovative business environment, acting as a catalyst for business creation and growth of young firms. It also plays a major role in financing new technology-based firms. Venture capital (seed and start-up) investment in Luxembourg is low by international comparison (OECD, 2014c, 2015a). The number and volume of projects that lend themselves to venture capital investment appears to have been modest in the past. Opportunities may increase as a result of the expansion and upgrading of Luxembourg's public research system, including the public research centres (CRPs), the university and its interdisciplinary research centres. Clustering of research and incubation activities at the Cité des Sciences at Esch-Belval may also help in this regard.

The intellectual property regime

Luxembourg is one of the few countries in the European Union where a single institution handles all intellectual property (IP) issues. The IP office under the Ministry of the Economy (MECE) is responsible for industrial property (patents, trademarks and

designs) as well as IP (e.g. author's rights). While the IP office handles administrative issues, the Luxembourg Technology Watch Centre offers products and services in support of businesses – particularly small and medium-sized enterprises – and other actors in the area of IP management. IP activities have been concentrated in an independent IP institute (Institut de la propriété intellectuelle Luxembourg) affiliated with MECE in 2015.

Luxembourg has a high level of IP protection, mainly provided by the Benelux Intellectual Property Convention, the 1992 patent law and the 2011 law on copyrights, related rights and databases. Luxembourg is a party to all the major conventions in such matters (e.g. the European Patent Convention, the Patent Co-operation Treaty and the Madrid Protocol). Innovators in Luxembourg may obtain protection in several ways:

- They can file an application with the Intellectual Property Service of the MECE.
- They can file a European patent application with the European Patent Office (EPO) in Munich, Berlin or The Hague.
- They can file an international patent application with the World Intellectual Property Organization in Geneva.

Patent applications to the Luxembourg office are rather inexpensive compared to other EU member states. Trademarks and designs can be directly registered for the Benelux region, at similarly low fees. IP litigation is dealt with by the local courts of justice, which may require a suspension of activity and impose penalties for infringements.

ICT and transport infrastructure

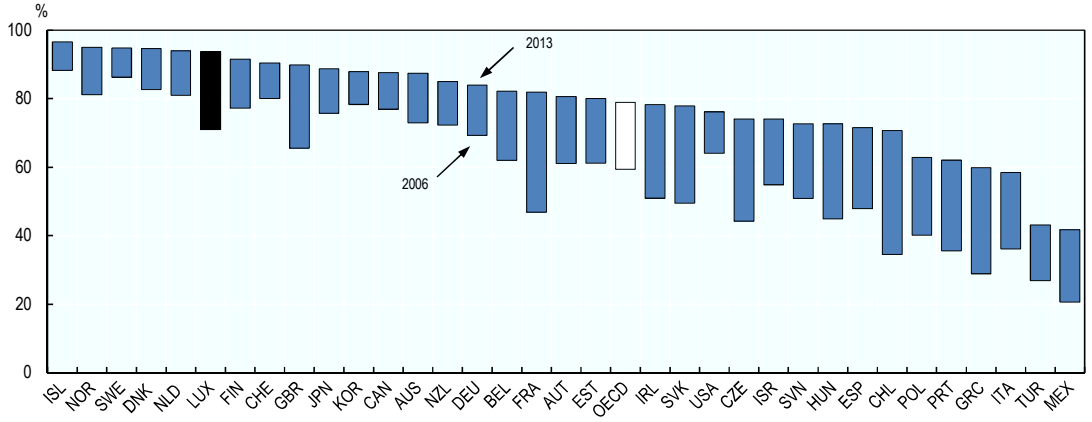
The ICT infrastructure is an important location factor in Luxembourg. It has gained in importance during the last decade and plays a role in the country's diversification efforts (Box 2.2). Luxembourg has a well-developed technological and communications infrastructure. Internet usage increased rapidly between 2006 and 2013, placing Luxembourg close to the leading Nordic countries and the Netherlands (Figure 2.9). Luxembourg is a leader in cross-border e-commerce (OECD, 2014d). Investment in ICT goods and services is an important driver of economic growth. In 2012, Luxembourg invested close to 1.5% of GDP in ICT – a considerably lower share, however, than in leading countries such as Denmark, Switzerland or Sweden, where ICT investments accounted for more than 3% of GDP. ICT investments as a proportion of gross fixed capital formation (GFCF) accounted for 6% in Luxembourg – again a significantly lower share than in innovation-intensive economies such as Denmark (19%), Switzerland (16%) or Sweden (17%) (OECD, 2014d).

In Luxembourg, the information industries sector contributes 7% of value-added, less than in Ireland (about 11%) but more than in Germany or Denmark (about 5%). ICT-related jobs accounted for 4.3% of total employment in 2013, placing Luxembourg in the top half of the group of comparator countries for which data are available – right behind Denmark and Switzerland (both around 4.5%), Sweden (5%) and Finland (6%). Despite its small size, Luxembourg accounted for 1% of total world exports in ICT services, surpassing Denmark, Norway or Switzerland. Worldwide, ICT firms tend to be more dynamic than firms operating in other sectors: between 2009 and 2012, net business population growth in the ICT sector stood at about 4.5%, compared to 1% in the business economy overall (OECD 2014d). ICT firms in Luxembourg followed this pattern, recording 5.4% growth against 2.9% for the overall business economy. The net growth of Luxembourg's ICT firms over 2009-12 was comparable to ICT firm growth in Denmark (5.6%) or

Belgium (5.3%) and higher than in Sweden (4.3%) or Ireland (3.2%). Luxembourg's ICT service firms – where medium and high-growth enterprises (in terms of employment) account for nearly one-fifth of the total number of medium and high-growth enterprises – are more dynamic than its ICT manufacturing firms. This is one of the highest shares among the comparator group of countries for which data are available.

Figure 2.9. **Internet usage trends in the OECD and differences by country, 2006-13**

By country change between 2006 and 2013



Source: OECD (2014d), *Measuring the Digital Economy, A New Perspective*, http://dx.doi.org/10.1787/9789264221796-en.

The performance of transport and logistics infrastructure and services is vital to realising the potential offered by Luxembourg's geographical location and promoting the country as a logistics hub (Box 2.2). Cross-country studies highlight the importance of a favourable geographical position for a high overall level of productivity.[5] Luxembourg combines transport by road, rail and air, complemented by services on the River Moselle. The road network has been modernised in recent years, including through providing motorway connections to neighbouring countries. Plans are afoot to introduce trams in the capital and light-rail lines in surrounding areas. Operated by Chemins de fer luxembourgeois, Luxembourg's railways link the most important towns. Its international routes extend to Trier, Brussels, Liège, Metz and Nancy, and connect to the Belgian, German and French rail networks. The high-speed TGV train service to Paris has reduced travel time to just above two hours. Luxembourg Airport at Findel is the country's commercial airport; its close geographical location proximity to major European markets and its infrastructure – including a 4 000 meter-runway and high slot availability – make it a significant European air freight platform. Luxembourg's international airline, Luxair, and cargo-only airline, Cargolux, operate from Luxembourg Airport.

2.3 The role of innovation in future development

During the early 20th century, Luxembourg transitioned from a largely agrarian economy to an industrialised one with an important steel industry, which dominated the economy during the years of recovery and growth in the aftermath of the Second World War. Its predominance lasted until the onset of the oil and steel crises of the 1970s, which announced its secular decline. Even at the height of the steel industry, however, Luxembourg managed to attract a number of important multinational enterprises (MNEs)

from other manufacturing areas. Key FDI projects included Goodyear (tyre production), DuPont de Nemours (polyester) and Monsanto (nylon). Beginning in the 1980s, the creation of new enterprises (supported by the newly established Société nationale de crédit et d'investissement), the development of industrial zones, the burgeoning financial sector and other policies and initiatives partly mitigated the decline of the steel industry.

Box 2.2. **ICT and logistics in Luxembourg**

In the **ICT sector**, Luxembourg, through its implementation of customised infrastructure in the domain of connectivity and data centres, has now become a location of choice for numerous companies, especially in the electronic content distribution and data storage sectors in a highly secure environment. Luxembourg, through significant investment in connectivity and in high security data centres, has forged a reputation over recent years of being a "European Trusted Information Center". The government intends making Luxembourg a world data bank for finance and the real economy. The development of the ICT sector will be achieved primarily through an increase of service providers, for example, through the extension of the draft law on electronic archiving, management of copyrights and intellectual property, the development of companies that use electronic services – for example a feasibility study of the implementation of a mini-one stop shop system for aligning administrative requirements – or yet the development of infrastructures and the arraying of a broadband internet network through the updating of the national strategy for implementing ultra broadband networks. The ICT sector is also the common feature between the other multi-sector specialisation. It is strongly tied to the logistics sector, through e-commerce, eco-technologies through smart grids and IT management, health technologies, with the archiving and management of data, space technology and the industrial and financial sectors, through high performance cloud computing.

With regard to the **logistics sector**, the government is seeking to position Luxembourg as an intercontinental and multimodal logistics platform in Europe, primarily in the domain of high added value logistics. As part of a multi-products policy, various categories have been identified as vehicles for synergies with other target sectors, especially pharmaceutical products. The work accomplished in the Eurohub Sud business area will be implemented in order to provide high performance infrastructures to serve the logistics sector. The Bettembourg multimodal terminal and rolling motorway platform will be developed in order to link with a growing number of destinations throughout Europe. The infrastructure of the tri-modal Port de Mertert platform will be renovated and developed to meet future requirements in the area of logistics. In order to facilitate procedures for importing, exporting and transit of merchandise, the Government will set up a "single window for logistics" system.

Source: Gouvernement du Grand Duché de Luxembourg (2014), *National Plan for Smart, Sustainable and Inclusive Growth. Luxembourg 2000*.

Luxembourg's second transformation – now towards a service economy – stemmed from the rise of its financial industry, clearly evidenced by the massive long-term shift in the value-added structure. Between 1970 and 2011, total industry's share in Luxembourg's value-added declined from 47% to 8%, and steel's share plummeted from 28% to 2% (Observatoire de la compétitivité, 2014). In parallel, the massive increase in financial sector value-added more than compensated for the decline of the steel industry. The Financial-sector has been the main engine of economic growth in the past three decades. Luxembourg's banking sector accounts for roughly one-quarter of GDP and is the largest in the European Union.

Luxembourg's development as a major international financial centre owes to a "combination of a 'first mover' strategy in implementing international regulation, low

taxation and strict banking secrecy rules" (Radu, 2014). Luxembourg's financial sector comprises investment funds, insurance companies and banks. The country hosts the second-largest fund-administration industry globally (Wintersteller, 2013). Most of the banks are foreign-owned subsidiaries that are weakly linked to the domestic economy through their operations. Numerous international companies are domiciled in Luxembourg, e.g. the leading steel and mining company Arcelor-Mittal, key players in the global entertainment and communication industry – e.g. eBay, Amazon, iTunes, CLT-UFA, SES-Global and the RTL Group – and many other global companies.

Luxembourg's large financial sector has weathered the financial crisis relatively well, despite challenges in aligning financial regulations with EU and other international initiatives. In the aftermath of the financial crisis, some fiscal and regulatory rules and practices have come under scrutiny. As many countries face tight budgetary constraints, international efforts to improve transparency (e.g. related to banking secrecy) have gained momentum, resulting in improved international information exchange; some preferential tax treatments have been challenged or phased out.

While the Luxembourgish economy has emerged from the crisis relatively unscathed, it faces major strategic tasks, which innovation policy can help accomplish.

- **Achieving and maintaining adequate productivity growth**: productivity is recognised as the main engine of long-term economic development and source of differences across (notably high-income) countries in GDP per capita. Luxembourg supports its high living standards with a high level of labour productivity. Multifactor productivity (MFP) – e.g. the joint efficiency of the production inputs, labour and capital – is the most important driver of labour productivity growth, typically ahead of increased capital intensity. In the most developed countries, innovation tends to drive MFP growth. Thus, long-run economic performance depends on the level and quality of a country's innovation activities, e.g. the ability to generate, transfer and assimilate technological, non-technological, managerial, organisational and institutional innovations. For a small country like Luxembourg, a high level of absorptive capacity to monitor, screen and adopt advancements in global science and technology is critical. Fulfilling these functions requires domestic research capacities.
- **Diversifying the financial sector as well as developing new high value-added economic activities in non-financial services and manufacturing industries:** in time, this would help reduce the economy's heavy reliance on the financial sector. In the aftermath of the crisis, it has become widely acknowledged that diversification can help strengthen economic resilience and mobilise new growth sources, notably through innovation-driven economic activities. High value-added activities tend to be technology- and knowledge-intensive, and require investment in human resources, R&D and innovation.

A major pillar of this overall effort towards economic diversification is Luxembourg's persistent effort to upgrade its innovation system by fostering investment – notably in its CRPs as well as the University of Luxembourg – and innovation in the business sector, while at the same time improving the governance mechanisms required to steer the system effectively. The country has achieved much in this respect in recent years, as subsequent chapters of this review will show in more detail.

After a period of rapid, largely government-financed expansion of the research (especially public research) and innovation system, and substantial reforms in its organisation

and governance (as well as that of its main institutional actors), Luxembourg's innovation system is now entering a new phase. This requires addressing major tasks:

- consolidating the progress made over the past decade, and further advancing to become a widely recognised location for research and innovation in Europe
- linking and orienting more effectively and strategically promising research and innovation initiatives that were initiated and flourished during the recent period of rapid growth and change
- improving governance and steering the innovation system in order to:
  - enhance co-ordination across ministries and agencies
  - strengthen linkages between the CRPs and the University
  - better target long-term funding to the most promising research areas and groups.

2.4 Innovation performance

Innovation inputs

The ability to mobilise resources for innovation differs markedly across countries. Advanced innovation systems devote considerable financial and human resources to STI. An assessment of the amount and quality of financial and human resources devoted to innovation covers a wide range of indicators related to R&D expenditures and skill characteristics across the population. These variables are described across different sectors – government, business and higher education – to assess the relative weight of actors in an innovation system.

Data on innovation inputs show that Luxembourg's public research system has considerably expanded since the early 2000s, thanks to the creation of the University of Luxembourg and expansion of the CRPs. Luxembourg benefits from a highly educated labour force, even compared with advanced OECD countries. However, indicators capturing the skill levels of secondary school students show a gap in their performance in Luxembourg compared with other innovation-intensive countries.

R&D expenditures and personnel

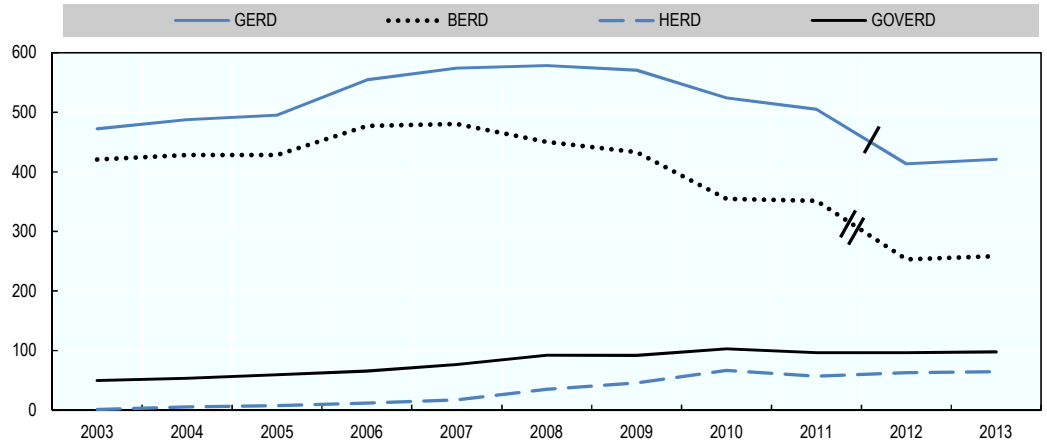
Luxembourg's gross domestic expenditure on R&D (GERD) of EUR 523 million in 2013 (equivalent to USD 421 million, PPP 2005 constant prices) was comparable to Estonia's (USD 442 million, PPP 2005 constant prices) and was higher than Iceland's (in 2011, USD 289 million, PPP 2005 constant prices). However, small innovation-intensive economies such as Israel (USD 9.9 billion, PPP 2005 constant prices) or Singapore (in 2012 USD 7.1 billion, PPP 2005 constant prices) invested significantly higher amounts. There are, of course, size differences: Israel numbered approximately 8 million inhabitants and Singapore 5.4 million, compared to Luxembourg's roughly half a million.

GERD rose from USD 472 million in real terms (at 2005 constant prices) in 2003 to a peak of USD 578 million in 2008 and declined after the crisis (Figure 2.10), owing primarily to a decline in business enterprise expenditure on R&D (BERD). It has to be noted, however, that – due to a revision by Luxembourg's STATEC – there is a break in the BERD and GERD time series in 2012. This break makes a direct comparison over time impossible. The break in series seems to be related to a variety of factors, including difficulties in measuring R&D expenditure and personnel in the financial sector and related services which may have resulted in an overestimation in the past. Moreover, STATEC made some changes in the data collection and validation process. The upward

trends of government expenditure on R&D (GOVERD) and higher education expenditure on R&D (HERD) reflect the rapid expansion of the public research system since the beginning of the 2000s. GOVERD rose from USD 30 million in 2000 to USD 103 million in 2010 and stabilised thereafter. HERD jumped from USD 1.6 million in 2003 – when the University of Luxembourg was established – to USD 64.5 million in 2013.

Figure 2.10. **Luxembourg's GERD and its components**

Business, higher education and government expenditure on R&D, million USD, constant 2005 prices and PPP



Note: Break in time series in 2012 for BERD and GERD.

Source: OECD (2014e), *Main Science and Technology Indicators,* http://dx.doi.org/10.1787/eco_outlook-v2014-2-en.

In 2011, about half (47.8%) of total R&D expenditure was funded by the business sector, compared to 30.5% by government institutions and 20.4% by funding from abroad (Table 2.1); 66.8% of R&D performed by businesses is funded by business. Business-sector funding of research in the very young higher education sector is low compared to innovation-intensive economies witch a long history in university-based research. Business funded less than 1% of R&D performed in higher education – well below the OECD average of approximately 6% (OECD, 2014e). It funded 6.5% of R&D performed by the government sector (e.g. largely by the CRPs) – more than the OECD average of around 3-4%.

The share of R&D financed by industry nearly halved over the 2000s, from around 90% of total R&D expenditure in 2000 to 48% in 2011 (Table 2.2). This can be largely explained by: i) the corresponding increase in the share of GOVERD (from approximately 7% in 2000 to more than 30% in 2011) related to the intended expansion of the public research system since the mid-2000s; and ii) the increase of GERD funded from abroad, from slightly over 1.6% in 2000 to more than 20% in 2010 and 2011.

GERD as a share of GDP (commonly referred to as national or aggregate R&D intensity) decreased from 1.57% in 2000 to 1.16% in 2013 (Figure 2.11), below the Lisbon Strategy objective of 3% for the European Union and below the OECD (2.40%) and EU (1.92%) averages. It should be noted however, that there was a break in the series for BERD and GERD in 2012, as mentioned above. More fundamentally, however, Luxembourg's comparatively low aggregate R&D intensity is largely attributable to structural factors. The country's GDP is exceptionally high, and a large share of it derives from the financial sector. This sector is typically not as R&D-intensive as traditional high-tech industries, and measuring its R&D expenditure poses some difficulties.

Table 2.1. **GERD by sector of performance and source of funds, 2011**

EUR million (percentages of performance in italics)

Source of funds \ Sector of performance	Business enterprise	Government	Higher education	Total (performance)
Business enterprise	278.2	7.4	0.5	286.1
	66.8%	*6.5%*	*0.7%*	*47.8%*
Government	x	x	64.7	182.6
	x	*x*	*95.9%*	*30.5%*
Higher education	x	0.4	0	0.4
	x	*0.3%*	*0%*	*0.1%*
Private non-profit	x	6.8	0.4	7.2
	x	*5.9%*	*0.6%*	*1.2%*
Funds from abroad	x	x	2.0	122.1
	x	*x*	*2.3%*	*20.4%*
Total (funding sector)	416.2	114.7	67.4	598.4
	100%	*100%*	*100%*	*100%*

Note: x = not applicable.

Source: OECD Science, Technology and R&D Statistics.

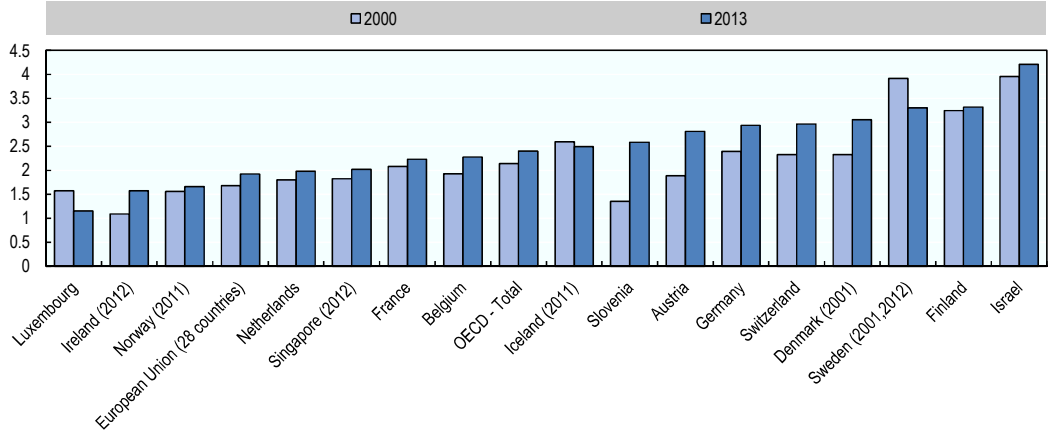
Table 2.2. **GERD by sector of funding**

Percentage

	2000	2003	2005	2007	2009	2010	2011
Industry	90.7	80.4	79.7	76.0	70.3	44.3	47.8
Government	7.7	11.2	16.6	18.2	24.3	34.8	30.5
Abroad	1.6	8.3	3.6	5.7	5.4	20.7	20.4

Source: OECD (2014e), *Main Science and Technology Indicators,* http://dx.doi.org/10.1787/eco_outlook-v2014-2-en.

Figure 2.11. **GERD as a percentage of GDP, 2000 and 2013 or latest available year**



Note: Break in time series in 2012 for GERD.

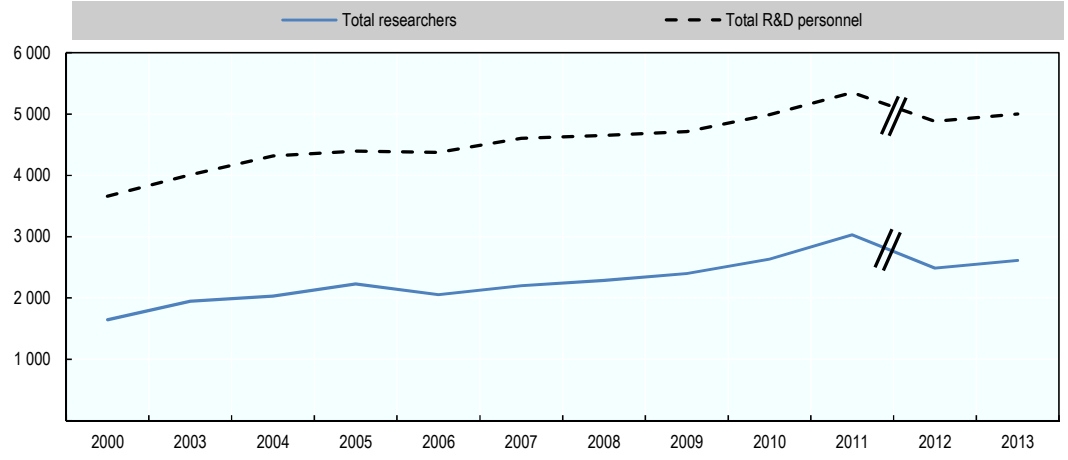
Source: OECD (2014e), *Main Science and Technology Indicators,* http://dx.doi.org/10.1787/eco_outlook-v2014-2-en.

R&D personnel

R&D personnel includes researchers and other support staff, such as technicians and managers. The evolution of the number of R&D personnel over time provides a perspective on the changing nature of countries' R&D activities. R&D expenditure and R&D personnel generally follow similar trends, for the simple reason that for the most part, R&D expenditure consists of the salaries of research personnel. However, the quantity (headcounts or, more informatively, full-time equivalents [FTE]) of R&D personnel does not capture their skill quality and deployment.

In Luxembourg, the number of R&D personnel and researchers (FTE) has grown since the beginning of the 2000s (Figure 2.12), from more than 3 600 in 2000 to over 5 000 in 2013. The number of business R&D personnel was approximately 3 500 in 2003 and 2 900 in 2013). As noted above, there is a break in the time series for business R&D personnel. R&D personnel employed in higher education and government has increased significantly. Between 2003 and 2013, R&D personnel more than doubled in the government research institutes sector (from almost 500 to slightly more than 1 000) (Figure 2.13); it increased almost 30 times over in the higher education sector, thanks to the establishment of the University of Luxembourg.

Figure 2.12. **R&D personnel and researchers (FTE) in Luxembourg, 2000-13**

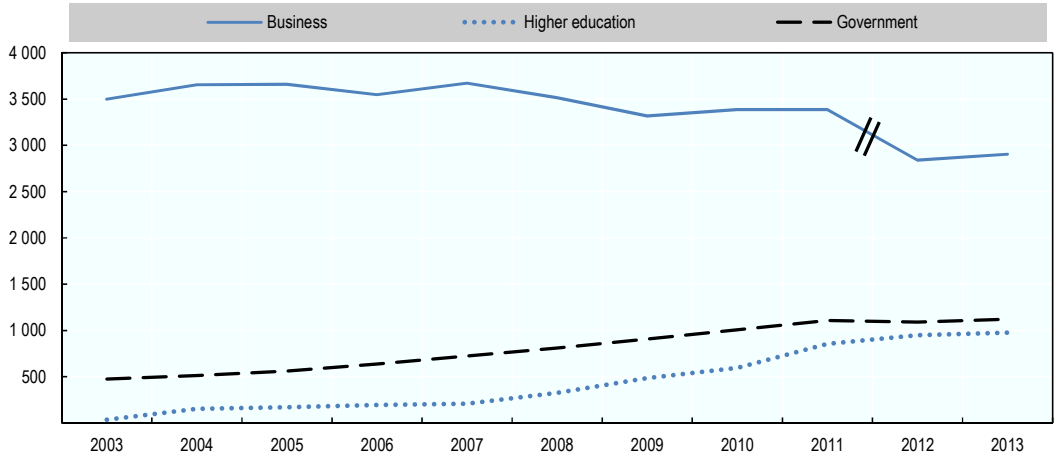


Note: Break in time series in 2012 for R&D personnel and researchers.

Source: OECD (2014e), *Main Science and Technology Indicators,* http://dx.doi.org/10.1787/eco_outlook-v2014-2-en.

From an international perspective, the number of total FTE R&D personnel in Luxembourg – 12.9 per 1 000 total employment – is in the lower range of the comparator group of countries with advanced innovation systems (Figure 2.14). Innovation-intensive countries such as Denmark (21.3), Finland (21.2) or Israel (21.1) have higher shares of R&D personnel.

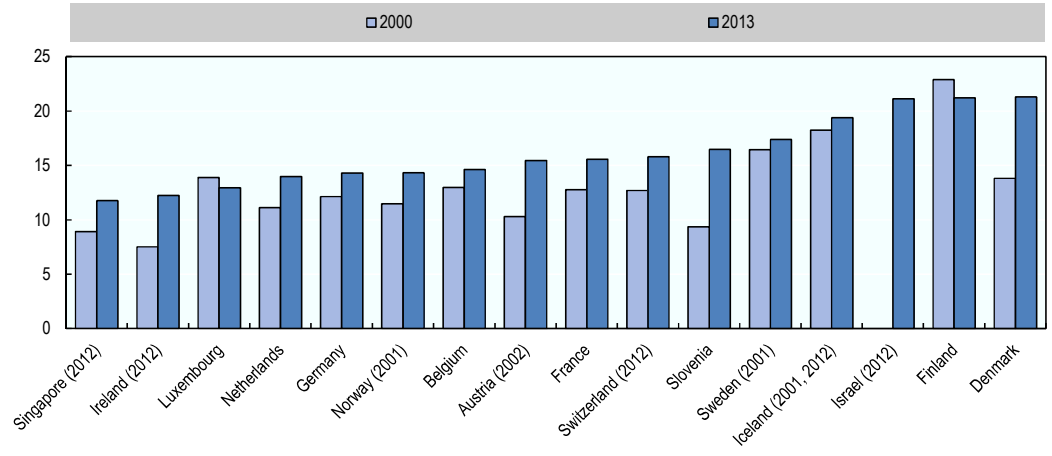
Figure 2.13. **R&D personnel (FTE) by sector**



Note: Break in time series in 2012 for business enterprise R&D personnel.

Source: OECD (2014e), *Main Science and Technology Indicators,* http://dx.doi.org/10.1787/eco_outlook-v2014-2-en.

Figure 2.14. **Total R&D personnel (FTE) per 1 000 total employment in selected countries, 2000 and 2013**



Note: Break in series in 2012 for the business enterprise R&D personnel.

Source: OECD (2014e), *Main Science and Technology Indicators,* http://dx.doi.org/10.1787/eco_outlook-v2014-2-en.

Human resources for STI

Human resources provide the foundations for knowledge-based economies and are thus a key issue for innovation policy. Human resources relate to innovation in a variety of ways (OECD, 2011). Skilled people generate knowledge that can be used to create and introduce an innovation; the academic literature has shown how an educated workforce contributes to the economy's innovation output (Carlino and Hunt, 2009; Gumbau-Albert and Maudos, 2009; Lin, 2009). In addition to generating new knowledge, higher skill levels raise economies' absorptive capacity and ability to perform incremental innovation,

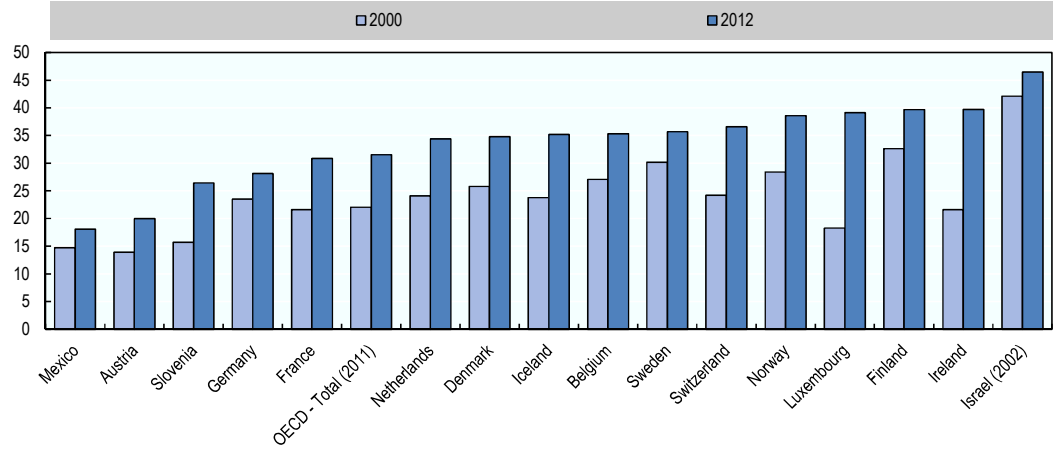
by enabling people to understand how things work and how ideas or technologies can be improved or applied to other areas (Toner, 2007). Leiponen (2000) found that innovating firms' profitability was significantly influenced by the level of employees' higher education, technical and research skills, in contrast to non-innovating firms. Human capital can also contribute indirectly to innovation through the "spillovers" generated by skilled workers – who not only diffuse their knowledge throughout their workplace and the wider environment, but also spur faster accumulation of human capital by other workers through their interactions and explicit or implicit actions. Finally, higher levels of human capital enhance social capital, which can support innovation in several ways –especially through its effect on trust, shared norms and networking – thereby improving knowledge efficiency and exchange. Some studies suggest that improved levels of trust can promote venture capital financing of risky projects, thanks to factors such as reduced monitoring costs (Akçomak and ter Weel, 2009). Firms with higher levels of social capital are also more likely to engage specialist knowledge providers, including from the public science base, to complement their internal innovation activities (Tether and Tajar, 2008).

Luxembourg benefits from large inflows of foreign researchers. In the area of public R&D, 82% of researchers are non-nationals, hailing predominantly from neighbouring countries. In the CRP Henri Tudor, for example, 46% of the staff are citizens of France, 11% of Luxembourg and 10% of Germany. In the University of Luxembourg as well, a considerable share of staff are German nationals.

Education and training

Tertiary educational attainment can serve as one of the broad measures of a country's ability to accumulate human capital of potential relevance to innovation. In 2012, Luxembourg reported high tertiary attainment rates in adults (39%), above the OECD (32%) and EU (28%) averages (Figure 2.15). Luxembourg's share is similar to that of advanced countries such as Norway or Finland and surpasses that of some innovation-intensive countries, including Switzerland or Denmark.

Figure 2.15. **Percentage of the population with tertiary education**



Source: OECD (2014f), *Education at a Glance. OECD Indicators*, http://dx.doi.org/10.1787/eag-2014-en.

The Programme for International Student Assessment (PISA) is a triennial international survey aiming to assess education systems by testing the skills and knowledge of 15-year-

old students. Table 2.3 shows countries' mean PISA scores for 2012 in mathematics, reading and science. In 2012, Luxembourg scored slightly below the OECD average in all three areas. In mathematics, Luxembourg scored 490 against the OECD average of 494; in reading, 488 against 496; in science, 492 against 501. Luxembourg's share of top performing 15-years-old science students increased from 5.8% in 2006 to 8.2% in 2012, but remains below that of most innovation-intensive countries, including the Netherlands (11.8%), Germany (12.1%), Finland (17.1%) and Singapore (22.7%). In mathematics and reading, the corresponding share of top performers in Luxembourg is lower than in many innovation-intensive economies, such as Belgium, Finland and Singapore. These scores suggest that the quality of the education system up to the secondary level lags behind the most innovation-intensive countries and cities examined in PISA.

Table 2.3. **Mean PISA scores, 2012**

	Mathematics	Reading	Science
OECD average	494	496	501
Shanghai, China	613	570	580
Singapore	573	542	551
Hong Kong, China	561	545	555
Chinese Taipei	560	523	523
Macao, China	538	509	521
Liechtenstein	535	516	525
Switzerland	531	509	515
Netherlands	523	511	522
Finland	519	524	545
Belgium	515	509	505
Germany	514	508	524
Austria	506	490	506
Ireland	501	523	522
Slovenia	501	481	514
Denmark	500	496	498
France	495	505	499
Iceland	493	483	478
Luxembourg	490	488	491
Norway	489	504	495
Sweden	478	483	485
Israel	466	486	470

Source: OECD (2014g), *PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science* http://dx.doi.org/10.1787/9789264208780-en.

The status of women in research

With a low share of female researchers in its innovation system (Table 2.4), Luxembourg lags behind other advanced economies with respect to gender parity in science and research. In the business sector, the share of female researchers is the lowest within the comparator group of countries – down from 14.2% in 2003 to 11.4% in 2011 – compared with a share of over 25% in countries such as Singapore, Iceland, Sweden, Slovenia, Denmark and Belgium. This low share owes partly to the predominance of business research activities in the automotive or ICT industries, where male employees generally outnumber female employees.

Table 2.4. **Female researchers by country and sector**

Females as a percentage of total, 2003 and 2012

Country	Business enterprise		Country	Government sector		Country	Higher education	
	2003	2011		2003	2011		2003	2011
Luxembourg	**14.2**	**11.4**	Germany	27.1	33.5	Singapore	27.2	33.1
Germany	11.6	14.7	Belgium	30.1	33.5	France	34.1	33.3
Netherlands	8.7	14.5	Netherlands	24.2	33.6	Switzerland (2002, 2010)	28.27	34.8
Austria (2002)	10.4	16.3	Switzerland (2002, 2010)	23.3	34.3	Germany	25.7	36.3
Finland	18.3	16.8	Singapore	32.3	34.6	Austria (2002)	34.6	38.9
Switzerland (2004, 2008)	21.0	18.7	**Luxembourg**	**28.5**	**34.8**	**Luxembourg**	**42.9**	**39.7**
France	20.3	19.6	France	32.0	35.04	Denmark	31.3	39.9
Israel (2007)	20.1	21.4	Ireland	30.6	35.7	Belgium	35.3	40.1
Ireland	20.3	22.3	Denmark	34.9	36.4	Netherlands	31.4	40.8
Norway	18.2	22.7	Iceland	42.1	42.3	Slovenia	32.9	41.8
Singapore	22.6	25.1	Finland	40.3	43.0	Ireland	37.9	42.1
Iceland	33.0	25.5	Austria (2003)	34.6	44.0	Sweden	43.7	44.4
Sweden	25.2	25.6	Norway	35.6	44.0	Norway	37.6	44.8
Denmark	24.5	26.0	Slovenia	41.5	47.9	Finland	44.8	47.0
Belgium	19.6	26.1	Sweden	36.4	50.0	Iceland	43.1	47.2
Slovenia	24.7	26.72						

Note: No data was available for Israel for the government and higher education sector.

Source: OECD (2014e), *Main Science and Technology Indicators,* http://dx.doi.org/10.1787/eco_outlook-v2014-2-en.

Innovation outputs

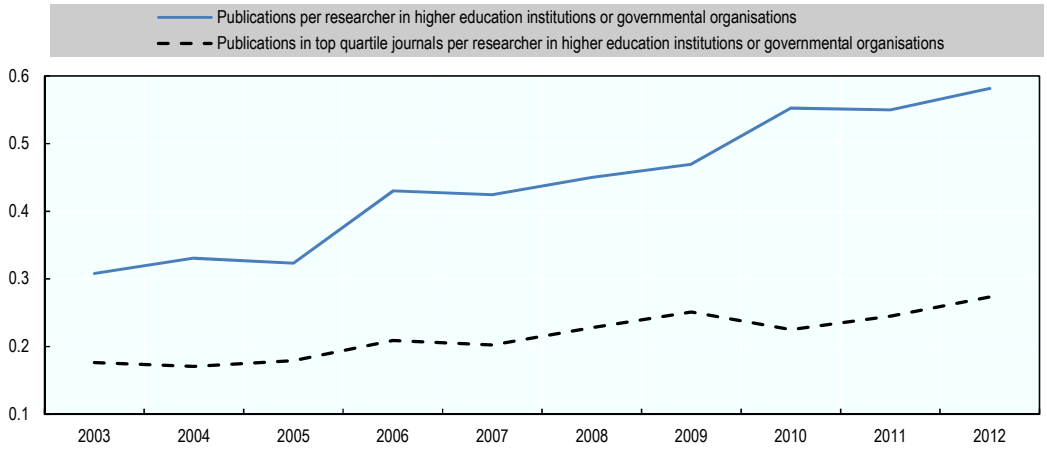
For a number of reasons, innovation outputs are difficult to measure. Available indicators only partially cover the various forms of innovation. Examples of available indicators are patents and scientific publications. While these measures of technological innovation and scientific output are readily available and often used, they are originally collected for other purposes and do not single out certain types of innovation activity. More generally, it is difficult to capture the level and qualities of process, organisational and marketing innovation – which are especially important to the services sector, which itself is critical to Luxembourg's economy. Further, the impact of innovation may differ greatly for every measurement increment. Such limitations mean that the picture obtained from aggregate indicators is inevitably partial, highlighting the need for long temporal and country coverage as well as further validation. Nevertheless, taken together, the various available indicators of innovation present an opportunity to map and assess innovation output systematically and consistently across countries and over time.

Scientific publications

The expansion of Luxembourg's public research system is reflected in the rapid growth of scientific publications, whose production increased more than 10 times over between 2000 and 2012, from 90 publications only in 2000 to more than 1 100 in 2012. Similarly, the number of publications per researcher in higher education institutions or government research organisations (a measure of the productivity of researchers in the public research system) has expanded considerably. However, indicators capturing the quality of scientific production reveal that Luxembourg still lags behind innovation-intensive economies. The pace of publications in top-quartile journals (a measure of quality of scientific production) per researcher has not increased as fast as

the total number of publications per researcher (Figure 2.16), and the gap between total and high-quality publications has widened since the late 2000s. Furthermore, the share of publications in top-quartile journals per researcher in Luxembourg in 2012 was the lowest in the comparator group of countries with available data (Figure 2.17).

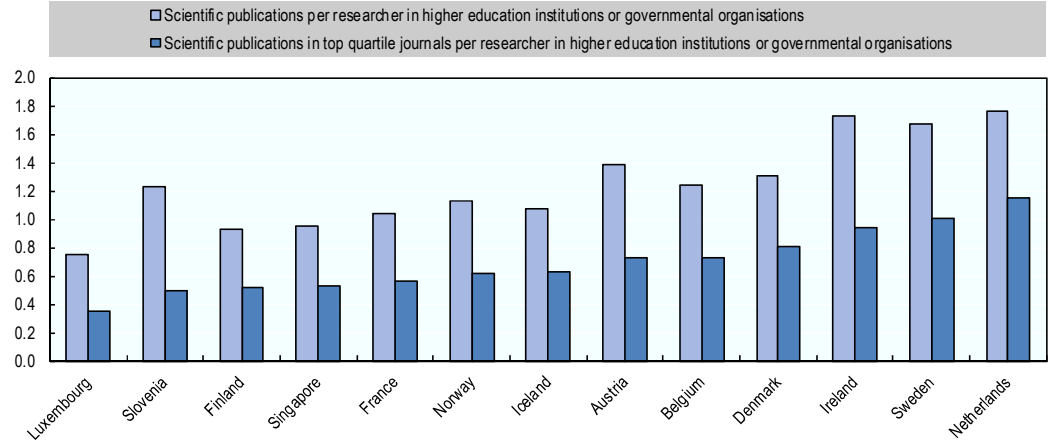
Figure 2.16. **The expansion of scientific production in Luxembourg**



Note: The percentage of first quartile publications (%Q1) refers to the ratio of publications that an institution publishes in the world's most influential scholarly journals, e.g. those ranking in the first quartile (25%) in their categories, as ordered by the SCImago Journal Rank (SJRII) indicator (www.scimagojr.com).

Source: OECD calculations based on Elsevier Research Intelligence/Scival (data retrieved online on 31 January 2014).

Figure 2.17. **Scientific performance, 2012**



Note: the number of scientific publications per researcher in higher education institutions or government organisations may reflect more or less accurately a country's scientific performance. Some countries where business-sector researchers tent to publish large volumes of scientific publications have been excluded from the comparator group, as the number of scientific publications divided by researchers in higher education institutions and government organisations may overestimate their scientific performance; %Q1 refers to the ratio of publications that an institution publishes in the world's most influential scholarly journals, e.g. those ranking in the first quartile (25%) in their categories, as ordered by the SCImago Journal Rank (SJRII) indicator (www.scimagojr.com).

Source: OECD calculations based on Elsevier Research Intelligence/Scival (data retrieved online on 31 January 2014).

Bibliometric indicators point to the high degree of internationalisation of Luxembourg's scientific research: more than 70% of top-cited scientific publications – the highest share in OECD countries – involve a foreign co-author. This figure reflects not only the small size of the country, but also well-established collaborations with neighbouring countries, as well as the high share of foreign R&D personnel in Luxembourg. In 2003, almost 40% of internationally co-authored publications involved a co-author from France, Germany or Belgium. This share decreased slightly to around 32% in 2012, mostly owing to an increase in co-authorship with researchers in the United Kingdom and the United States.[6] Thus, the increase in scale and scope was accompanied by a wider geographic reach of collaborative activity.

Patents

International patenting is used as an indicator of economically valuable technological inventions. This indicator is particularly relevant for developed innovation systems, especially if they have a strong manufacturing sector. Given the large size of the service economy – especially the financial sector – patents may not be the most appropriate measure of Luxembourg's innovation output. Moreover, firms' patenting behaviour and patent acquisition in a given country may be strongly influenced by the prevailing IP frameworks and other relevant regulations.

One measure of international patenting that is particularly relevant to European countries is the number of patent applications filed under the EPO. Inventors resident in Luxembourg applied for an average of 87 patents a year at the EPO over 2010-12. This number is higher than the yearly average of Iceland (19) but lower than Slovenia's (118). For cross-country comparisons, patent applications are often related to population size. At 167 patent applications per million population on average over 2010-12 (Table 2.5), Luxembourg is close to the median of the comparator group of countries, but much less patent-intensive than countries such as Switzerland (323), Sweden (300) or Finland (290).

Table 2.5. **Patenting intensity**

Patent application per million population, 2010-12

	Average 2001-03	Average 2004-06	Average 2007-09	Average 2010-12
Switzerland	380	432	423	434
Sweden	235	270	296	298
Germany	268	290	290	286
Finland	257	259	242	260
Denmark	187	212	233	232
Austria	161	192	202	212
Netherlands	231	226	217	199
Luxembourg	**170**	**234**	**167**	**167**
Israel	152	191	165	151
Belgium	127	147	141	138
France	123	134	136	132
Norway	81	99	106	107
OECD – total	99	108	100	101
Ireland	61	69	76	76
Iceland	97	103	76	61
Slovenia	35	55	70	58
Singapore	50	60	55	52

Source: OECD patent statistics databases, www.oecd.org/sti/inno/oecdpatentdatabases.htm.

Notes

1. GDP is an aggregate measure of production equal to the sum of the gross values added of all resident institutional units engaged in production (plus any taxes, and minus any subsidies, on products not included in the value of their outputs). GNI is GDP less primary incomes (compensation of employees and property income) payable to non-resident units plus primary incomes receivable from non-resident units.
2. The exception is the education and skills dimension of the index.
3. According to estimates in the OECD *Economic Survey of Luxembourg* (OECD, 2015) more than 80% of unemployment is structural. The Survey adds the caveat that structural unemployment, as well as potential output, is difficult to estimate in a small open economy with as high a share of cross-border workers and as large a financial sector as Luxembourg.
4. It should be noted, however, that estimates of potential growth and its components are beset by added uncertainty from specific characteristics of Luxembourg's economy, such as the large share of cross-border workers in the labour force and difficulties in measuring the value-added of the financial sector with large inflows and outflows of capital (see Annex 1 of Chapter 2 in OECD, 2015).
5. Boulhol and de Serres (2010) suggest that the benefits of a favourable location may be as high as 6% of GDP for Belgium and the Netherlands.
6. OECD calculations based on Scopus Custom Data, Elsevier, version 4.2014, June 2014.

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Chapter 3.

Innovation actors in Luxembourg

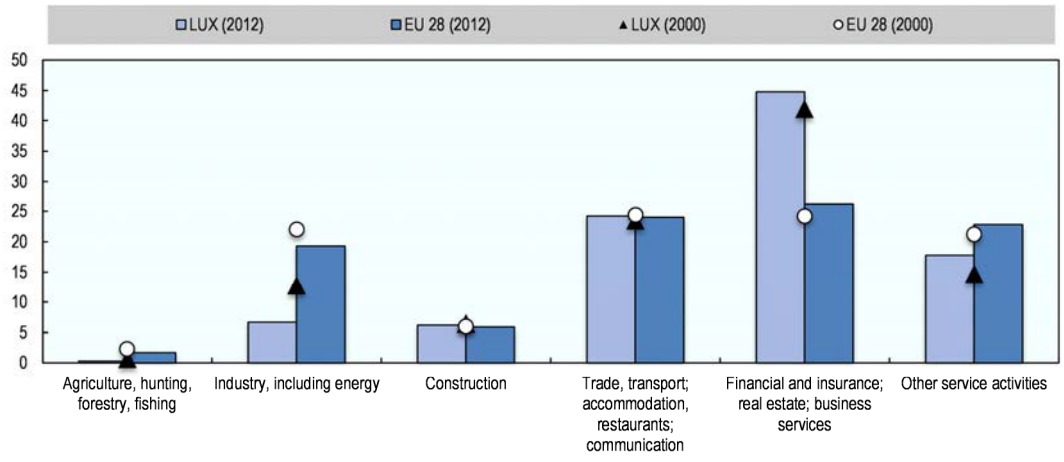
This chapter describes the main actors in the Luxembourg innovation system – business enterprises, the University of Luxembourg and public research centres – highlighting their respective roles in the development of the innovation system in recent years. It reviews scientific, technological and related functions carried out by the main actors within the system and their contributions to innovation.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

3.1 Business sector

Luxembourg's business sector has been strongly shaped by the interplay between the economy's small size, openness to international trade and investment, and its geography at the intersection of four major euro area economies (Belgium, France, Germany and the Netherlands). Having transitioned from agriculture to a steel manufacturing hub over the course of the early 20th century (Zahlen, 2007), Luxembourg entered a second successful transformation in the wake of the decline of the steel industry. Luxembourg's current affluence owes much to the success of its financial sector and development of its service industries, more generally in the latter half of the 20th century. Today, Luxembourg is primarily a service economy, with a strong financial services sector. In 2012, financial and related services, such as insurance and business services, accounted for just under half of value-added in Luxembourg (against one-quarter in the European Union [EU28]), whereas manufacturing and other industrial activity accounted for less than one-tenth (against one-fifth in the EU28) (Figure 3.1). This specific feature of Luxembourg's industrial structure can be understood in light of the importance of banking, financial and ancillary services, and its importance in global value chains – particularly as a transborder regional economic centre and destination for high value-added foreign investment.

Figure 3.1. **Value-added by activity, 2000 and 2012**



Source: OECD (2014), *OECD Factbook 2014: Economic, Environmental and Social Statistics*, http://dx.doi.org/10.1787/factbook-2014-en.

Luxembourg's top employers are mostly multinationals and state-linked companies (Table 3.1). Thanks to its geographic position, good framework conditions and proactive policy towards investment (including through different types of business regulation), Luxembourg is a very attractive location for foreign direct investment. Many multinationals choose to locate critical parts of their global operations in Luxembourg, including their headquarters operations through on-site holding companies (Clancy, 2008). Goodyear, Delphi and DuPont are examples of multinationals with research and development (R&D)-intensive teams operating in Luxembourg (Box 3.1).

Table 3.1. **Main employers, 2012**

Employer	Number of employees
State	25 278
ArcelorMittal Group	5 960
BGL BNP Paribas	4 110
Cactus Group	3 920
CFL Group	3 810
Entreprise des Postes et Télécommunications Group	3 800
City of Luxembourg	3 680
Goodyear Dunlop Tires Operations SA	3 080
Dussmann Luxembourg Group	2 790
Luxair SA	2 400
PricewaterhouseCoopers Group	2 110
Dexia BIL Group	2 100
Centre hospitalier de Luxembourg	2 060
Centre hospitalier Emile Mayrisch	1 870
Banque et caisse d'épargne de l'État, Luxembourg	1 770
RBC Dexia Investor Services Bank SA	1 580

Source: STATEC (2015), *Entreprise* (database), www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=9859&IF_Language=fra&MainTheme=4&FldrName=1.

Small and medium-sized enterprises (SMEs) make up the bulk of Luxembourg's business sector (Table 3.2). They account for almost 68% of value-added and 67% of employment in the country, compared to 58% of value-added and 67% of employment in the European Union. An idiosyncrasy of Luxembourg's business sector is that micro-enterprises (with fewer than ten employees) account for a higher share of value-added (22%) than of employment (18%); EU average figures generally show a reverse trend. The high share of Luxembourg micro-enterprises likely reflects some of the high-value activities in small businesses linked to the financial sector and ancillary activities, including investment companies (wealth managers, dealers, custodians, distributors of shares in undertakings for collective investment, etc.) and related or complementary businesses (brokers, financial advisers, company domiciliation agents, etc.). Examples of ancillary services include computer service suppliers, auditing and consulting firms, investment-fund management companies, compensation and settlement bodies, fiduciaries, corporate lawyers and notaries (OECD, 2008a).

Table 3.2. **Firm demographics, 2013**

	Number of enterprises			Number of employees			Value-added		
	Luxembourg		EU28	Luxembourg		EU28	Luxembourg		EU28
	Number	Share	Share	Number	Share	Share	EUR billion	Share	Share
Micro	25 658	86.9%	92.4%	44 318	17.9%	29.1%	4	21.8%	21.6%
Small	3 129	10.6%	6.4%	61 967	25.0%	20.6%	4	20.5%	18.2%
Medium-sized	605	2.0%	1.0%	58 511	23.6%	17.2%	5	25.5%	18.3%
SMEs	29 392	99.5%	99.8%	164 796	66.6%	66.9%	14	67.9%	58.1%
Large	144	0.5%	0.2%	82 742	33.4%	33.1%	6	32.1%	41.9%
Total	29 536	100.0%	100.0%	247 538	100.0%	100.0%	20	100.0%	100.0%

Source: European Commission (2014), *2014 SBA Fact Sheet Luxembourg*.

Box 3.1. Examples of innovation-intensive companies in Luxembourg

Goodyear Luxembourg

With approximately 3 100 employees, Goodyear is one of the largest private companies in Luxembourg. Located in Colmar-Berg, Goodyear Luxembourg is one of the most diversified sites of the Goodyear Group outside the United States. The main installation of the industrial complex, the Tire Plant, produces tires and civil engineering components. To meet high quality standards, Goodyear established the Goodyear Innovation Center Luxembourg (GIC*L), its largest R&D centre outside the United States, which carries out research and development work, and builds and tests new tires for passenger cars, light and medium trucks and farm vehicles for the European, African and Asian (EMEA) markets. A staff of over 900 engineers, scientists and technicians of 29 different nationalities work on new raw materials, tread designs and rubber quality. The main function of GIC*L is to provide technical support to 25 Goodyear EMEA production facilities, obtain approvals from vehicle manufacturers worldwide, maintain close contact with markets and customers through regularly scheduled product analysis, and guarantee the quality of tires and the good introduction of the products in 185 countries.

Delphi

Delphi is one of the leading suppliers of individual components and complete systems for the automotive industry and beyond. The Delphi Luxembourg site opened in Bascharage in 1971. The Luxembourg technical centre focuses on design, development and testing of components, systems and sub-systems related to energy and engine management; heating, ventilation and air conditioning; power and control electronics; and energy storage for hybrid and electric vehicles. The technical centre is equipped with vehicle wind tunnels, multiple vehicle engine and component test stands, and laboratories for noise and vibration measurements and electromagnetic compatibility. It also develops and manufactures prototypes. Luxembourg also hosts the global headquarters of Delphi Powertrain Systems, a company that develops and applies components and systems for managing passenger-car gasoline and diesel engines. Delphi and the Interdisciplinary Centre for Security, Reliability and Trust (SnT) of the University of Luxembourg co-operate on a joint research programme that involves developing effective and efficient automated verification and validation technologies for electronic control unit software systems.

DuPont de Nemours

DuPont opened its Luxembourg site in 1962. The company aims to create innovative and sustainable solutions in material sciences for use in various fields. DuPont develops and produces polyester films, elastomer polymers and spun-bonded materials for home construction, electronics, chemical protection, medical packaging, transportation, road construction and other key markets. DuPont has 1 150 employees in Luxembourg, 39 of whom specialise in R&D. The R&D section of DuPont de Nemours co-operate regularly with the public research centres (CRPs) Henri Tudor and Gabriel Lippmann, as well as local companies with specialised knowledge.

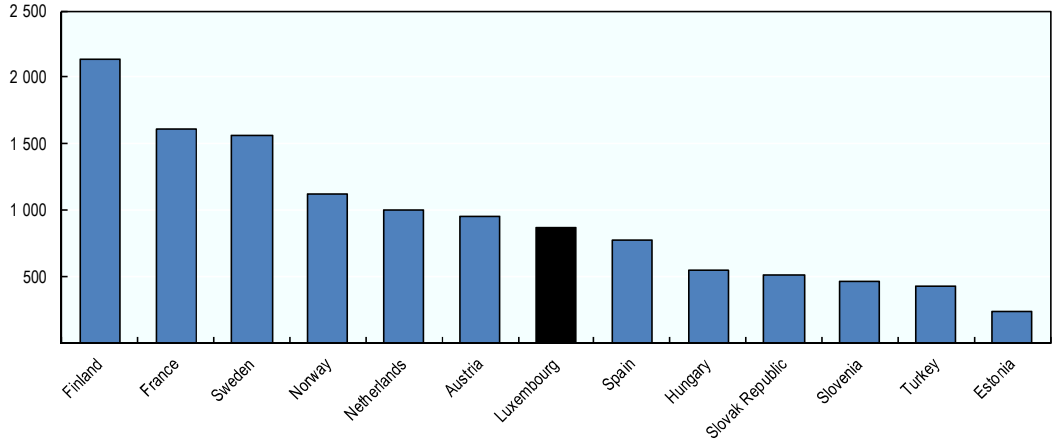
Source: Rieder et al. (2014), *The Luxembourg Innovation System*; Luxembourg Portal for Innovation and Research, www.innovation.public.lu/application/catalogue/entreprises/goodyear-innovation-center-luxembourg/pdf_en_goodyear-innovation-center-luxembourg.pdf.

Innovation and R&D performance

Firms' average innovation expenditure (Figure 3.2) is a broad indicator of the scale of innovative effort, not only for R&D but also for the purchase and integration of the latest

capital goods, new-process implementation, training and additions to the firm's stock of accessible knowledge (such as licences). As a measure of the scale of expenditure deployed within a firm's boundaries, average innovation expenditure can be expected to be higher in countries with a high number of larger firms. According to the 2010 Community Innovation Survey (CIS), the average innovating firm in Luxembourg spent about EUR 900 000 on innovation – an expenditure in the same order of magnitude as that of Austria and the Netherlands, two countries where large firms account for a greater share of employment and value-added than in Luxembourg.

Figure 3.2. **Average innovation expenditure per innovating company, 2010**



Note: Germany and some non-EU member states are missing due to lack of data. At the time of writing, data on innovation expenditure from CIS 2012 were not available.

Source: OECD, based on Eurostat (2015).

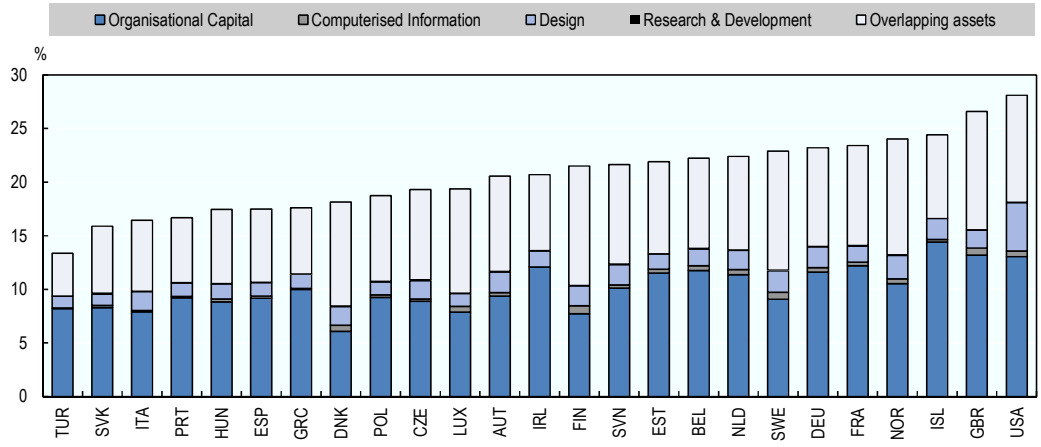
Though not necessarily related to actual innovation activities, another way to look at firms' innovation capabilities is from the perspective of knowledge-based employment and related capital investments. In OECD countries, knowledge-intensive activities – such as design and various aspects of engineering – account for a much larger share of employment and investment than R&D. OECD estimates on the basis of tasks performed, skills and knowledge areas suggest that in 2012, about 19% of workers in Luxembourg were employed in occupations contributing to R&D, design, software and database activities, and organisational know-how (Figure 3.3). Luxembourg has a lower share of knowledge-based capital workers than the usual comparator countries (Austria, Ireland, Finland, Slovenia, Netherlands, Germany, France, Norway and Iceland), owing in large part to lower shares in organisational capital (namely, the organisational know-how that increases enterprise efficiency).

In 2013, Luxembourg's business expenditure on research and development (BERD) amounted to about 0.7% of GDP. BERD intensity is low compared to that of innovation-intensive economies. A break in the time series in 2012 (notably due to the changes in the measurement of software-related activities) makes a direct comparison over time impossible. The same applies to the number of business-sector researchers (Figure 3.4).

An examination of BERD trends across broad sectors of economic activity (Figure 3.5) shows that the drop in 2010 was largely due to financial and insurance activities (down EUR 46 million) and manufacturing (down EUR 29 million).

Figure 3.3. **Knowledge-based capital workers, 2012**

% of total employed persons

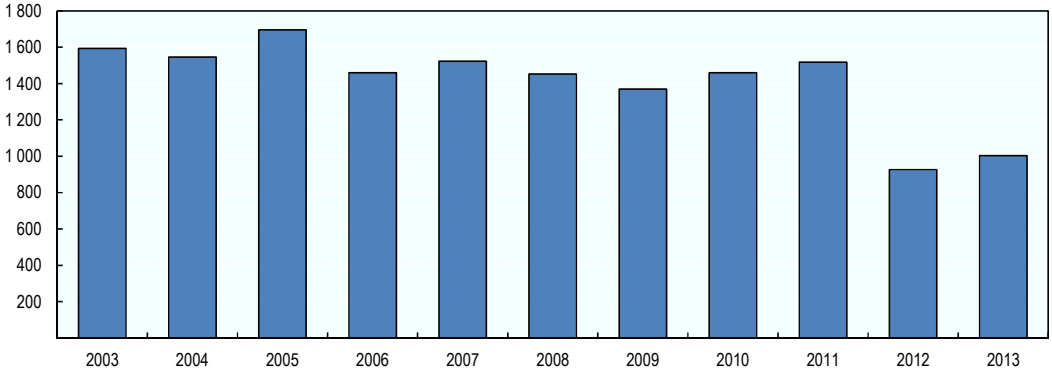


Note: workers contributing to R&D, design, software and database activities and to firms' organisational know-how account for between 13% and 28% of total employment in many OECD countries (total length of the bar). Of these workers, between 30% and 54% contribute to more than one type of knowledge-based capital asset (bar "overlapping assets"). R&D is difficult to discern in this graph as it accounts for less than 1% in all countries.

Source: OECD (2013), *OECD Science, Technology and Industry Scoreboard 2013*, http://dx.doi.org/10.1787/sti_scoreboard-2013-en.

Figure 3.4. **Number of researchers in the business sector, 2003-13**

Full-time equivalents



Note: Break in time series in 2012.

Source: OECD (2015), *OECD Main Science and Technology Indicators* (database), http://dotstat.oecd.org.

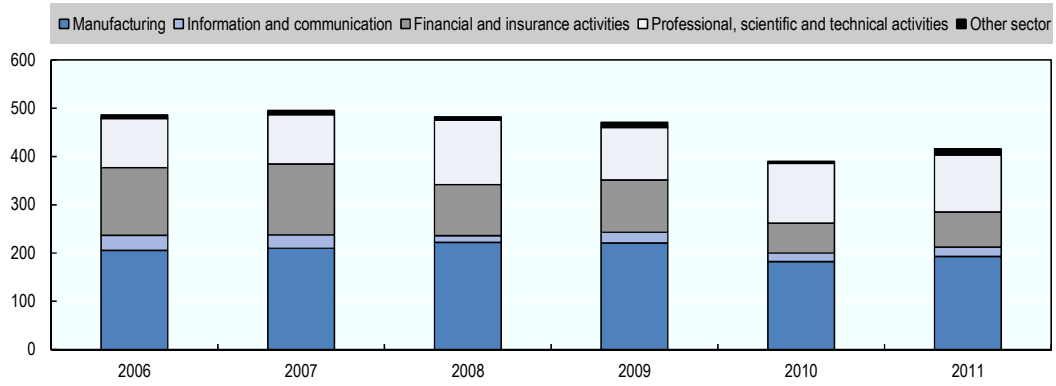
Patterns of innovation output

Evidence from the EU CIS suggests that a strong majority (66.1%) of Luxembourg firms introduced product, process, marketing or organisational innovations over 2010-12,

significantly above the European average of 48.9% (Eurostat, 2013). The rates do not differ much between firms operating in manufacturing (67%) (Figure 3.6) and services (66%) (Figure 3.7). Marketing and organisational innovation is typically more prevalent in services than manufacturing; inversely, product and process innovation is more common in manufacturing than services. International evidence suggests that the productivity impact of different modes of innovation varies across countries and that no single innovation mode is superior (Frenz and Lambert, 2012). Other international studies have shown that different innovation modes can be complementary, implying that firms that engage in multiple modes of innovation are generally likely to benefit the most. It is therefore encouraging that a relatively high share (41% for manufacturing and 35% for services) of Luxembourg firms engages in multiple modes of innovation (in both product/process and marketing/organisational innovation).

Figure 3.5. **BERD, 2006-11**

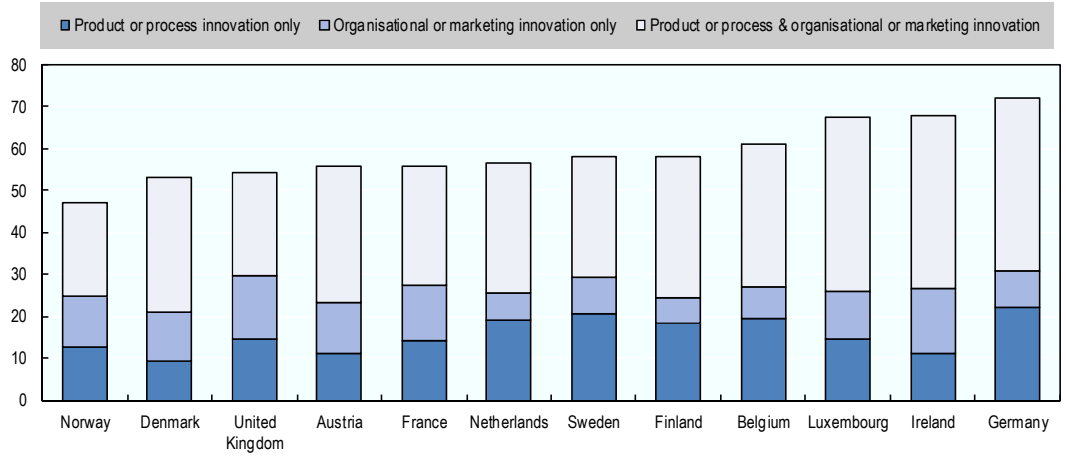
in EUR million



Source: Ministry of the Economy and Foreign Trade (2013), "2013 Competitiveness Report. Ten Years of Competitiveness Scoreboard: A Sawtooth Evolution".

Figure 3.6. **Innovation in the manufacturing sector, 2010-12**

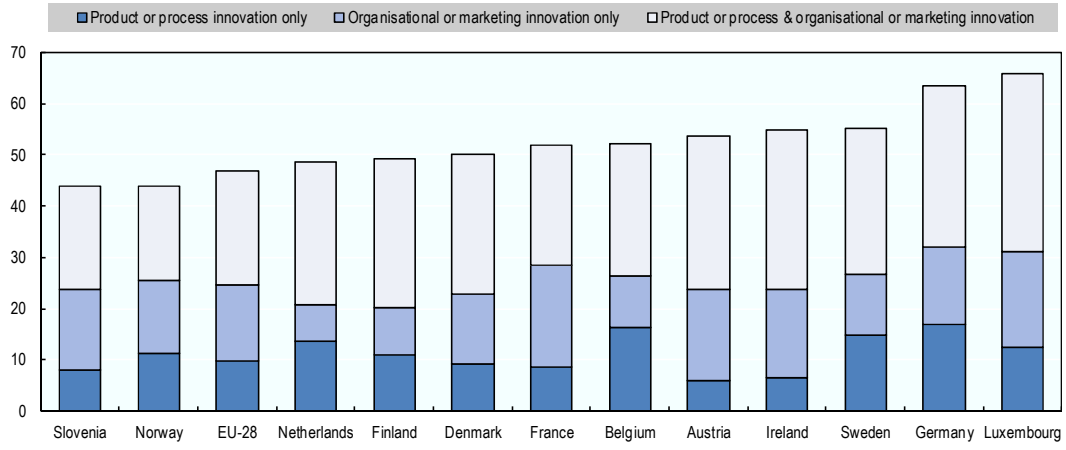
% of all manufacturing firms



Source: Eurostat (2013), *Seventh Community Innovation Survey. Highest Proportions of innovative Enterprises in Germany, Luxembourg and Belgium*.

Figure 3.7. **Innovation in the services sector, 2010-12**

% of all firms in core service activities



Note: Core service activities include the following NACE Rev 2 classes 46-H-J-K-71-72-73.

Source: Eurostat (2013), *Seventh Community Innovation Survey. Highest Proportions of innovative Enterprises in Germany, Luxembourg and Belgium*.

According to CIS 2012 data, collaboration on innovation activities between Luxembourg firms and public research organisations (e.g. public research institutes (PRIs) and universities) is generally weaker than in the comparator group of countries, especially with respect to collaboration with universities (Table 3.3). Interpretation of this indicator is complicated by the fact that the denominator is the total number of innovating companies, rather than the population of companies at large. In Luxembourg, about 7% of innovating companies collaborate with universities to carry out their innovation activities – a share that lags behind all other countries in the comparator group – and 8% of innovating companies collaborate with PRIs. As in other countries, the share of collaborating companies increases with firm size. All types of collaboration – except that between large firms and universities – have exhibited a decreasing trend since the previous survey, CIS 2010. Again, low collaboration rates partly owe to the large role of the service sector – which is typically less R&D-intensive and therefore establishes fewer linkages with PRIs and universities – in the economy. In Luxembourg, for example, 6.5% of firms from the service sector collaborate with universities, and 7.2% collaborate with PRIs. According to CIS 2012, shares are higher in the manufacturing sector, where 8.6 % of firms co-operate with universities and 9.1% with PRIs.

Factors affecting business innovation

Figure 3.8 presents companies' self-reported barriers to innovation activity featured in CIS 2010 (no data were available at time of writing for this specific question in CIS 2012 for Luxembourg). Whereas companies in the comparator group of countries perceived lack of finance as the leading issue, this is not the case for companies in Luxembourg. Rather, the dominant position of established firms and lack of demand are identified the main inhibitors to innovation activity. Difficulty in finding co-operation partners ranked higher in Luxembourg than in the comparator group countries.

Table 3.3. **Collaboration between companies and higher education institutions (HEIs) and companies and PRIs by firm size, 2010-12**

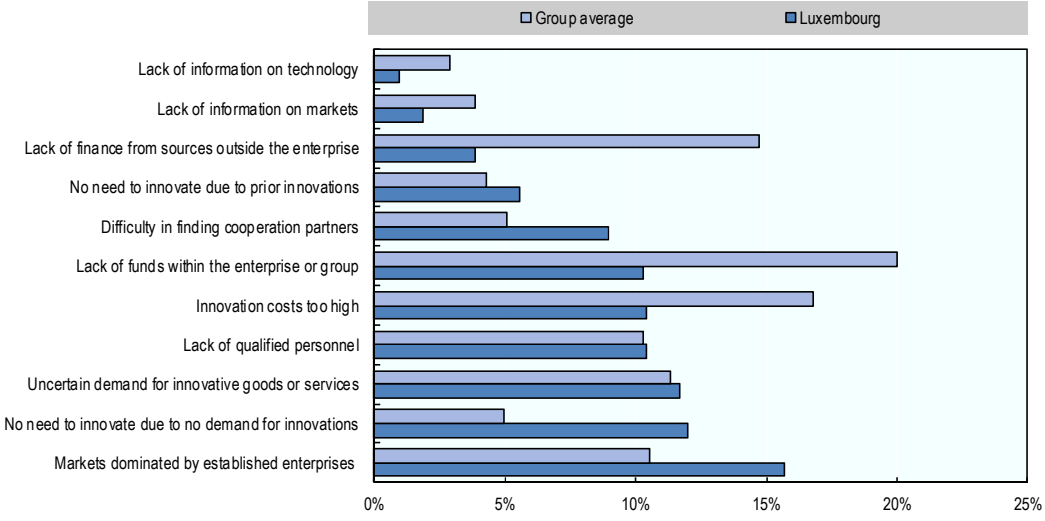
Share of innovative companies, %

	Collaboration with universities or other HEIs				Collaboration with PRIs			
	Firm size bands (numbers of employees)			Total	Firm size bands (numbers of employees)			Total
	10-49	50-249	250 or more		10-49	50-249	250 or more	
Belgium	15%	23%	42%	18%	12%	15%	33%	14%
Denmark	10%	19%	40%	15%	8%	13%	27%	11%
Germany	10%	18%	40%	14%	7%	13%	28%	10%
Ireland	9%	15%	32%	12%	4%	6%	12%	5%
France	8%	15%	32%	12%	6%	10%	23%	8%
Luxembourg	**5%**	**7%**	**27%**	**7%**	**5%**	**9%**	**23%**	**8%**
Netherlands	9%	13%	28%	11%	7%	9%	19%	8%
Austria	16%	26%	51%	22%	10%	15%	34%	13%
Slovenia	16%	36%	50%	25%	13%	26%	35%	19%
Finland	19%	33%	68%	26%	16%	30%	64%	23%
Sweden	14%	21%	45%	18%	--%	14%	34%	11%
Norway	9%	16%	37%	13%	10%	17%	40%	14%

Source: based on Eurostat (2015).

Figure 3.8. **Barriers to innovation activity, 2008-10**

Share of innovative enterprises (including enterprises with abandoned/suspended or ongoing innovation activities) considering the barrier as highly important



Note: Comparator group countries include: Belgium, Ireland, France, Slovenia, Finland, Sweden, Iceland and Norway. Data for Luxembourg are not available in the CIS 2012.

Source: based on Eurostat (2015).

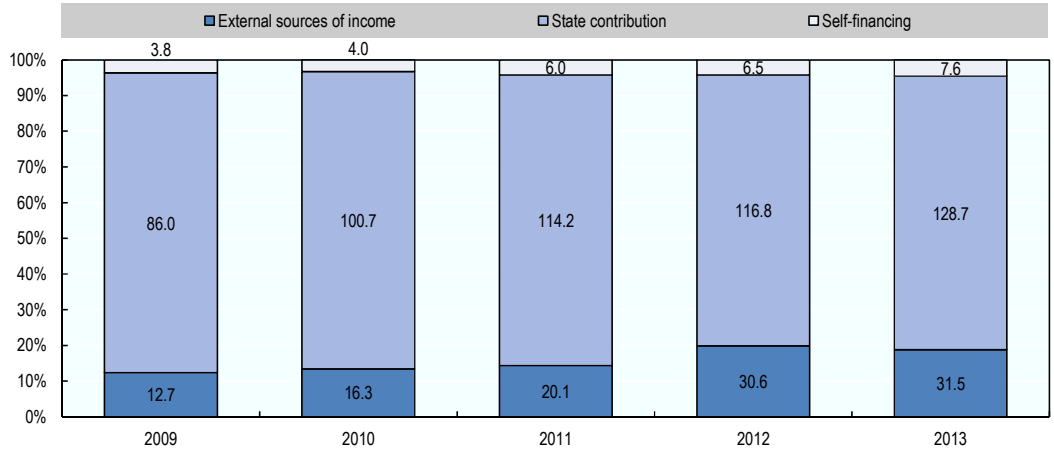
3.2 University of Luxembourg

A key structural development in Luxembourg's innovation system was the creation of the University of Luxembourg in 2003. The University is a small-sized institution numbering around 6 200 students and 1 460 staff aiming at excellence in research and

education in a few selected areas. It had revenues of EUR 168 million in 2013, with 77% coming from a government block grant and 19% from external funding – a mix of contractual and competitive research funding from the Fonds national de la recherche (FNR), European projects, businesses and government ministries (Figure 3.9).

The University is located on four different campuses: Kirchberg, Limpertsberg, Walferdange and Belval. Over the next few years, most of the University will be relocated to the Cité des Sciences in Belval.

Figure 3.9. **University of Luxembourg revenues, 2009-13, million EUR (MEUR)**



Source: University of Luxembourg (2014), *Report 2013: Key Performance Indicators*.

The University was founded by bringing together four existing institutes involved in higher education (and some research) in Luxembourg: the Centre universitaire, the Institut supérieur de technologie, the Institut supérieur d'études et de recherches pédagogiques and the Institut d'études éducatives et sociales. Meyer (2009) has characterised this collection of institutes as a "loosely-coupled system" marked by a relative lack of co-ordination, differences in methods, aims and missions, little lateral interdependence and a general "invisibility" of activities. Yet many decision-makers continued to openly oppose the creation of a university, arguing that Luxembourg was too small to host its own institution, that even without research and higher education Luxembourg was a prosperous country, and that students' need to study at foreign universities was an enriching experience for them and for Luxembourg. Importantly, it was the idea of creating a university focused on teaching *and* research, rather than a teaching-only university, that made it more palatable and neutralised some of the arguments against it. This coincided with a significant change in perspective on the very purpose of a university, from knowledge diffusion (primarily through teaching) to knowledge production (primarily through research), positioning the university within the discourse on diversifying the national economy (Meyer, 2009).

The OECD 2007 Review of Luxembourg's innovation policy (OECD, 2007) applauded the decision to create a research university, but identified obstacles related to the merger of established structures with new ones. In particular, broadening the University's focus beyond education and training to encompass strong research capabilities would likely create serious tensions for the University. These tensions have

been partially managed by establishing interdisciplinary centres strongly focused on research outside of the faculty structure, as described below.

The University comprises three faculties that engage in both teaching and research – the Faculty of Science, Technology and Communication (FSTC); the Faculty of Law, Economics and Finance (FDEF); and the Faculty of Language and Literature, Humanities, Arts and Education (FLSHASE). Each has historical roots to institutes that predate the University's establishment. In addition to the faculties, two semi-autonomous interdisciplinary centres – the SnT and the Luxembourg Centre for Systems Biomedicine (LCSB) – were founded in 2009 to further strengthen the University's research performance.

While the number of staff employed in the faculties has continued to grow steadily (Figure 3.10), the research-intensive interdisciplinary centres have seen the most spectacular growth. Across the University in 2013 16% of staff were faculty members (academic staff) and 57% were other scientific and research staff. A relatively high proportion (52%) of the academic staff were full professors; 26% were women, up from 20% in 2010. Academic staff recruitments account for just a small share of recent growth in staff numbers, compared to the very high contingent of other scientific and research staff (Figure 3.11). The interdisciplinary centres made up the bulk of these new appointments, accounting for 25% of total (excluding central administration) staff in 2013 (Figure 3.12), even though they represented less than 3% of academic staff (Figure 3.13). The University continues to increase its international profile: in 2013, 22% of staff hailed from Luxembourg, 45% from neighbouring countries (France, Belgium and Germany), 19% from other EU28 member states and 14% from other countries.

Figure 3.10. **Evolution in numbers of total staff (headcounts) in different parts of the University, 2008-13**

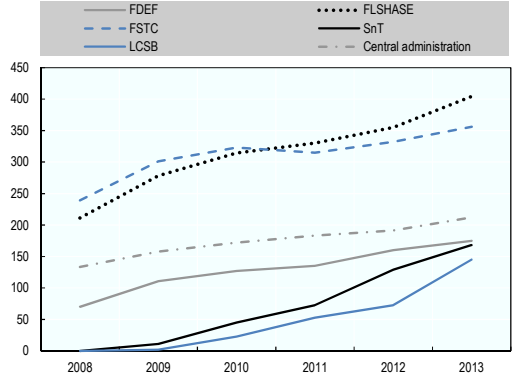
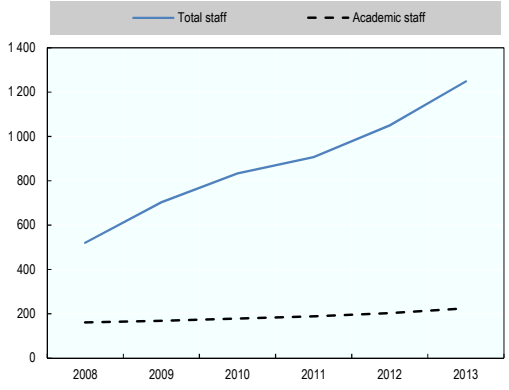


Figure 3.11. **Evolution of numbers of total and academic staff (headcounts), 2008-13**



Source: Various annual reports of the University of Luxembourg.

Training activities

Nearly 6 200 students enrolled at the University of Luxembourg in 2013/14 – a 20% increase over 2009/10. Bachelor's programmes account for more than half of students enrolled. While the share of bachelor's students has remained more or less stable (representing 53.4% in both 2006/07 and 2013/14), their numbers have almost doubled (from 1 784 in 2006/07 to 3 288 in 2013/14). Vocational training courses leading to

diplomas and certificates accounted for 18.5% of enrolled students in 2013/14 – nearly half the high of 34.4% in 2006/07 – even though the number of enrolled students was similar (1 150 in 2006/07 and 1 141 in 2013/14). Postgraduate programmes have grown the most rapidly in recent years: master's enrolments soared from 259 in 2006/07 to 1 183 in 2013/14 (i.e. 19.2% of all enrolments), while the number of students enrolled in doctoral (PhD) programmes rose from 148 to 545 over the same period (Figure 3.14, Panel a). This growth is in line with the University's ambition to become more research-oriented. However, the share of postgraduate students – 34.4% of all "Bologna" students (i.e. all students except those registered for vocational courses) – is slightly under the University's performance contract target of 37%.

Figure 3.12. **Percentile distribution of total staff in the faculties and interdisciplinary centres, 2013**

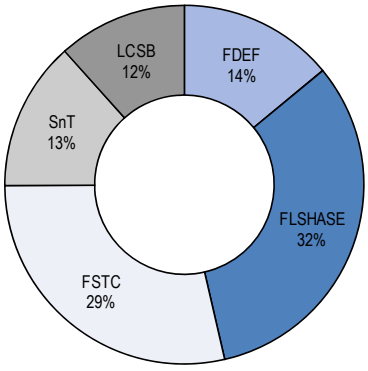
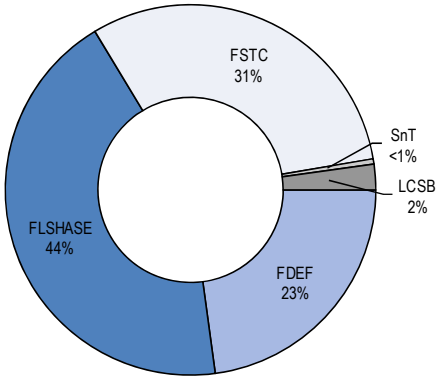


Figure 3.13. **Percentile distribution of academic staff in the faculties and interdisciplinary centres, 2013**



Source: University of Luxembourg (2014), *Report 2013: Key Performance Indicators*.

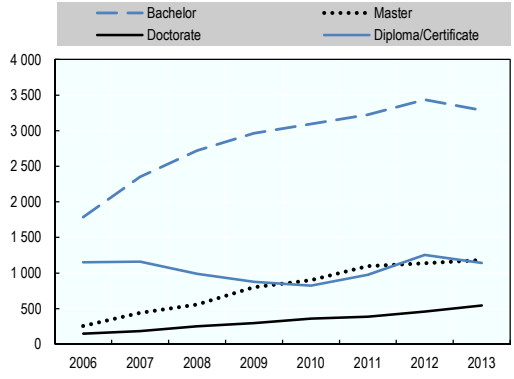
All three faculties offer bachelor's, master's, doctoral and vocational courses (Figure 3.14, Panel b):

- The FDEF offers three bachelor's and eight master's courses and has two doctoral schools (in law; and economics and finance). The country's vibrant international financial sector, the proximity of several European institutions and the presence of innovative industries form natural allies for the Faculty as evidenced by the number of sponsored academic chairs and professionals teaching select courses. The Faculty has the largest number of enrolled students – 2 628 in 2013/14 – in the University. It also accounts for close to two-thirds of the University's diploma/certificate enrolments.
- The FLSHASE offers 4 bachelor's and 14 master's courses and has three doctoral schools (in educational sciences; identities, politics, societies and spaces; and social sciences). It had 2 225 enrolled students in 2013/14.
- The FSTC offers four bachelor's and ten master's courses and has two doctoral schools (in systems and molecular biomedicine; and computer science and computer engineering). It had 1 304 enrolled students in 2013/14. Despite being the smallest faculty in terms of total student enrolments, it has the highest number of doctoral students: 268 in 2013, i.e. 21% of the total number of students enrolled in the faculty.

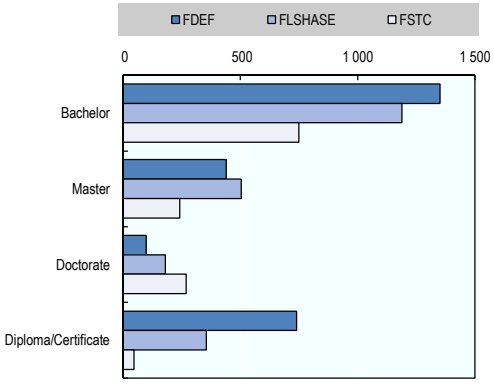
The most popular subject group at the University is business and administration (24% of all students), followed by education (16%): arts and humanities (12%); science, mathematics and computing (12%); law (12%); and social and behavioural sciences (11%); engineering lags far behind, (just 4% of students). Some bachelor's courses are seriously under-subscribed and could be either discontinued or delivered in partnership with other institutes in the Grande Région. Furthermore, graduation rates for bachelor's degrees are below University targets. The ease of entry into bachelor's courses likely contributes to the high dropout rates – where entry requirements are more stringent, dropout rates are lower.

Figure 3.14. **Evolution of student numbers at the University of Luxembourg**

Panel a: Number of enrolled students by programme level, 2006-13



Panel b: Number of enrolled students, by faculty and programme level, 2013



Source: University of Luxembourg (2014), *Report 2013: Key Performance Indicators*.

The 2003 law creating the University states that a bachelor's degree may be conferred only if a student has attended another university or higher education institution (HEI) abroad for a required period (typically one semester). Students are increasingly opting to spend this time in foreign HEIs beyond the neighbouring countries. The University student body is also very international, particularly at the PhD (83% of non-domestic enrolments) and master's (69%) levels.

Research activities

The University conducts research in its three faculties and two interdisciplinary centres (Box 3.2). The faculties feature several research units:

- FDEF: Research Unit in Law; Research in Finance (Luxembourg School of Finance); and the Centre of Research in Economic Analysis.
- FLSHASE: Education, Culture, Cognition and Society; Integrative Research Unit on Social and Individual Development; and Identities, Politics, Societies and Space.
- FSTC: Computer Science and Communications Research Unit; Research Unit in Engineering Science; Mathematics Research Unit; Physics and Materials Science Research Unit; and Life Sciences Research Unit.

Box 3.2. The University of Luxembourg interdisciplinary centres

The SnT

SnT was created to take the lead on implementing the University's focus on information technology security and reliability. This priority is particularly pertinent for Luxembourg, which has for some time sought to position itself as a European centre of excellence for secure, reliable and trustworthy information and communications technology systems and services. Like the LCSB, SnT has experienced fast and steady growth in terms of staff members, doctoral students, industry partners and public grants since its creation in 2009. By the end of 2013, it numbered 222 R&D personnel (including doctoral students and interns), including 17 faculty members. A key defining feature is its Partnership Programme, where key actors contribute know-how and resources to shape and build SnT; 20 such partnerships, involving a mix of public and private organisations, already existed in 2013. That year, SnT spent EUR 11.5 million on R&D; externally funded projects – mostly through various FNR schemes, but also through the Partnership Programme (16%) – accounted for 69% of the total. The Programme is notable for relying upon strategic mid- and long-term research partnerships with strongly committed industry or research players, rather than on short-term service-type projects that are more typical of the industry relationships permeating the more applied research-oriented CRPs. The strategy of SnT is that public funding for high-risk fundamental research should be done in concert with, rather than separately from, more practice-oriented partnership projects. The scientific review panel associated with the 2013 evaluation of the University recommended expanding partnerships further afield – starting with stronger relationships with international institutes – to drive excellence. It also highlighted the unclear division of labour with the FSTC, and its focus on academic research.

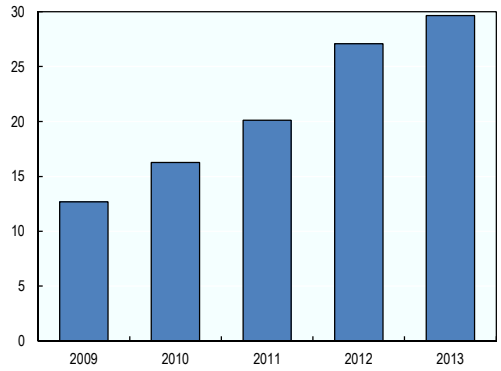
The LCSB

The LCSB originated in the Luxembourg government's Health Sciences and Technologies Action Plan and was built through a partnership with leading United States (US) institutes specialising in systems biology. Its aim is to carry out fundamental research in the field of systems biology and biomedicine, as well as analyse the mechanisms of disease pathogenesis, with a special focus on neurodegenerative diseases and more specifically Parkinson's disease. By the end of 2013, the LCSB employed more than 140 R&D personnel, including only 7 faculty members; the remainder are supported by a mix of University funding, FNR studentships and fellowships, FNR research grants, EU Seventh Framework Programme/Horizon 2020 funding and funding from other national sources. In 2013, the LCSB secured more than EUR 13 million in research grants. According to the scientific review panel associated with the 2013 evaluation of the University of Luxembourg, the LCSB fills a niche that is not yet over-populated. The panel was impressed with its performance, judging it to be "very good" and firmly on track to becoming "excellent". At the same time, the panel raised concerns about inadequate facilities at Belval and the need to improve collaboration with other parts of the University, notably related research units in the FSTC.

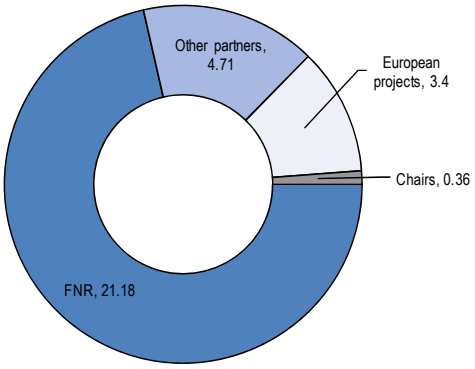
In 2013, the University secured almost EUR 30 million in third-party funding for research, up from EUR 16 million in 2010 (Figure 3.15, Panel a). This is above its performance contract target to secure EUR 23 million of external funding annually by 2013 and reflects in part the University's increasing professionalisation of grant-income support through its Research Service. It also reflects the growing strengths of the interdisciplinary centres, which have been especially successful in securing grant income. More than 70% of external funding for University research was sourced from the FNR in 2013, and 11% from European projects (Figure 3.15, Panel b).

Figure 3.15. **External funding for research at the University of Luxembourg**

Panel a: Growth of external funding for research, MEUR, 2009-13



Panel b: Breakdown of external funding for research, by funding source, MEUR, 2013



Source: University of Luxembourg (2014).

The University also exceeded its performance indicator target of achieving a publication intensity of two refereed publications per researcher for the duration of the 2010-13 performance contract (Table 3.4). The number of citations of University publications has also increased markedly –from 289 *Web of Science* citations in 2007 to 3 491 in 2013.

Table 3.4. **Publications of the University of Luxembourg, 2010-13**

Type of publication	2010	2011	2012	2013
Refereed conference proceedings	x	341	391	383
Refereed journals	x	385	468	633
Published books	81	67	64	84
– Authored books	*x*	*34*	*32*	*31*
– Edited volumes	*x*	*47*	*32*	*53*
Book chapters	x	208	241	145
Publication Intensity (refereed publication/researcher full-time equivalent)	2.23	2.38	2.24	2.61

Note: x = not applicable.

Source: University of Luxembourg (2014), *Report 2013: Key Performance Indicators*.

Reflecting its ambition to achieve international visibility in a few research areas, the University has identified a number of research (and teaching) priorities. These are intended to provide a reference framework for the University when hiring new staff, with a view to strengthening scientific competences in selected fields. The University revisits its priorities every four years to coincide with the cycle of performance contracts negotiated with the government. The University's current four-year strategic plan (2014-17) identifies the following (central) research priorities:

- Computational sciences: this refers to the interdisciplinary combination of mathematical modelling and computer science/computer engineering with specific applications to various scientific domains, such as physics, engineering and life sciences. The FSTC and the two interdisciplinary centres are highly involved in computational science research. Prioritisation is intended to consolidate and strengthen existing competences with new positions in the relevant fields.

- Law, stressing European law: the presence of the Court of Justice of the European Union makes this an obvious priority. Prioritisation will not so much lead to further increasing the number of academic staff, as to strengthening its European character and buttressing its collaboration with the newly founded Max Planck Institute for International, European and Regulatory Procedural Law (see Section 3.4).
- Luxembourg School of Finance: the importance of international finance for Luxembourg makes this another obvious priority for the University.
- Educational sciences: improving Luxembourg's education system is a long-term project requiring a research-based understanding of the social and historical dynamics of Luxembourg's society and the role of its education system. Prioritisation is intended to translate into targeted appointments to enhance the University's excellence and international status in the field of educational research.

The University's strategic plan also sets four so-called "other" priorities, covering the following areas: physics and materials science; entrepreneurship and innovation/audit; multilingualism and intercultural studies; and sustainable development. In addition, the two interdisciplinary centres are identified as a separate class of priorities. Taken together, this is a broad set of priorities, covering much of the University's research and teaching activities. Considerable continuity exists with earlier articulations of priorities – which is hardly surprising given their breadth; there are also some divergences, as different parts of the University – e.g. the interdisciplinary centres – build new capabilities. In most instances, prioritisation appears to translate into some modest top-up funding (a projected EUR 100 000-200 000 per year for each priority area in 2014-17), to be used by the faculties and interdisciplinary centres to make a few additional staff appointments.

The 2013 evaluation of the University highlighted the lack of visibility of faculty research, which hampers recruitment of top talent. By contrast, the two interdisciplinary centres are increasingly visible at the international level and provide a major boost to the University's research profile. Their independent status lends them considerable agility and has allowed them, for example, to install swift recruitment procedures and to expand very rapidly. At the same time, such autonomy risks disconnecting them from the faculties, and weakening the links between research and teaching activities. Differences in contracts, workload distribution and promotion tracks contribute to tensions between interdisciplinary centre staff and the faculties. Tensions also arise over the University's allocating the bulk of its block grant to the faculties, despite the interdisciplinary centres' strong research performance.

The University has previously committed to developing a whole-of-university research strategy that would define present and novel strategic areas. This strategy has yet to be developed. The 2013 evaluation of the University highlighted the need for a University-wide research strategy. It recommended that the University's central administration develop, together with all parties concerned, a clear and balanced strategy on the relationship between faculties/research units, the interdisciplinary centres and the University's overall priorities, also taking into account the relationships between research, teaching and valorisation. The evaluation committee viewed such a strategy as an opportunity for the University to promote a common understanding of "research quality" and the means to monitor, improve and reward it, as well as provide clarity on the meaning and utility of research priorities.

Notwithstanding the pressures of the upcoming move to Belval, the University should articulate and implement such an inclusive whole-of-university research strategy as soon as possible. Among other things, the strategy should aim to set University research priorities;

define the meanings, relevance and implications of research excellence; delineate a fair reward system for research excellence and relevance among faculty research units and interdisciplinary centres; clarify the relationships between interdisciplinary centres and faculties; consider the merits of establishing further interdisciplinary centres; and define relationships with external actors, including the CRPs and international research partners. The research strategy process could also include a review of how other young universities have successfully developed on the basis of strong research capabilities – a couple of well-known examples are briefly described in Box 3.3.

Box 3.3. **Leading "young" universities in Europe**

The École Polytechnique Fédérale de Lausanne (EPFL)

EPFL is a technical university established in 1969 in Lausanne, Switzerland. It covers disciplines in basic sciences, engineering, architecture and life sciences. Almost 10 000 students from 112 countries were enrolled in EPFL courses in 2014 (of which approximately 2 600 are master's and 2 000 doctoral students). EPFL employed more than 5 500 staff in 2014, including doctoral students. The 2014 EPFL budget amounted to approximately EUR 850 million, 72% of which was funded by the Swiss Government and 28% from competitive and contractual funding – including grants from the Swiss National Science Foundation (10.2%), European programmes (6.4%) and industrial contracts (6.7%). It was the fourth most successful institution in Europe in terms of received European Research Council grants during the Seventh Framework Programme period.

EPFL is part of the Swiss Federal Institutes of Technology Domain (ETH Domain), which groups the two Swiss Federal Institutes of Technology (ETH), namely EPFL and ETH Zurich, as well as four research institutes. The Swiss Federal Council and the Swiss Parliament define the ETH Domain's overarching objectives. The ETH Board defines the strategy of the organisations within the ETH Domain; operational and managerial responsibilities lie within the organisations themselves. EPFL students can take courses, as well as undertake internships or part of their doctoral research at the four research institutes of the ETH Domain.

EPFL ranks 2nd in Europe and 21st in the world in the Leiden ranking of 750 major universities worldwide; 1st in Europe and 2nd in the world in the Times Higher Education ranking of universities less than 50 years old; and 3rd in Europe and 19th in the world in the Shanghai ranking of engineering/technology/computer science universities.

Universitat Pompeu Fabra (UPF)

UPF is a public university established in 1990 in Barcelona, Spain. UPF focuses on three main areas: social sciences and humanities; health and life sciences; and information and communications technologies. Nearly 10 000 undergraduate students, 1 800 master students, 1 200 doctoral students were enrolled at UPF in 2013/14. In 2013, UPF had almost 600 teaching and research staff, including 339 permanent professors and over 650 administrative staff. The UPF budget in 2014 was EUR 124 million.

UPF pays particular attention to its internationalisation strategy: 22% of its faculty is international and 30% of its graduate students studied abroad before joining UPF. In addition, UPF has signed agreements with 27 of the top 50 universities in the world (Times Higher Education ranking 2013) and has run a summer school programme with the UCLA since 2012. UPF ranks among the top 20 European universities in terms of the number of ERC-funded projects.

UPF is well positioned in 2014 international university rankings: according to the Times Higher Education ranking of universities less than 50 years old, it ranks 13th in the world; according to the Shanghai ranking, it is among the top 400 universities in the world and is the top Spanish university in social sciences.

Sources: www.epfl.ch; www.upf.edu/en.

Valorisation activities

The government's performance contracts with the University include performance indicators for patenting and licensing. In the 2010-13 contract, the University was expected to obtain five patents and two licences a year. Table 3.5 shows that while the University met its patenting target over the period of the performance contract, it missed its licensing target every year except for 2013. The latest performance contract (2014-17) raises these targets further, to 12 patents and 6 licences a year. In addition, the government expects the University to set up three spin-off companies every year.

Table 3.5. **Patents and licences of the University of Luxembourg, 2010-13**

	2010	2011	2012	2013	2010-13
Patents	4	2	5	12	23
Licences	1	1	-	2	4

Source: University of Luxembourg (2014), *Report 2013: Key Performance Indicators*.

The gross revenues generated from the commercial exploitation of a patent owned by the University of Luxembourg are equally shared between the University and the inventors who helped implement the invention. Such arrangements are common in other OECD countries. The University's Legal Affairs Office provides administrative and legal support to researchers seeking to commercialise their research findings. Luxinnovation also offers support. More recently, SnT has piloted arrangements to support the creation of research-based spin-off companies. These could be rolled out across the whole University.

3.3 Public research centres

The R&D law of 1987 established three major public research centres: CRP Gabriel Lippmann, CRP Henri Tudor and CRP Santé. In early 2015, CRP Gabriel Lippmann and CRP Henri Tudor merged to become Luxembourg Institute of Science and Technology (LIST), and CRP Santé has been renamed the Luxembourg Institute of Health (LIH). LIST focuses on research in three main areas – environment, information technology and materials (see Box 3.4) – while LIH focuses on clinically oriented biomedical research and public health (Box 3.5). The Luxembourg Institute of Socio-Economic Research (LISER) (formerly CEPS/INSTEAD) performs both basic and applied research in areas such as population and employment, geography and development, and business and industrial organisation, with the aim of informing social policy making in Luxembourg (see Box 3.6). All these centres are under the direct responsibility of the Ministry of Higher Education and Research.

The recent merger and name changes have been introduced as part of a wider amendment of the law establishing the CRPs. A new CRP law (2014) cements the status of the CRPs as autonomous public legal entities with financial and administrative autonomy, and alters the terms of their relationship with the Ministry of Higher Education and Research. Specifically, the role and composition of the administrative board of each CRP have changed: boards are no longer called upon to take all management decisions related to their CRPs; instead, they are expected to define the general policy and strategy of the CRP in keeping with the objectives defined by law and specified in the multiannual performance contracts with the government. CRP chief executives have greater autonomy to implement the strategy defined by the board and to take all decisions relating to the day-to-day management of the CRP. The law also views legally institutionalised performance contracts as the medium through which the government and CRPs agree on

the general orientation, goals and strategic choices of the CRP, as well as the funds provided by the government. Chapter 4 discusses these arrangements extensively. The law also introduces more transparent and open recruiting procedures for researchers.

Box 3.4. **The Luxembourg Institute of Science and Technology (LIST)**

LIST describes itself as a research and technology organisation (RTO) active in the fields of materials, environment, and information technology (IT). It was created in 2015 from the merger of CRP Gabriel Lippmann and CRP Henri Tudor, designed to achieve greater critical mass and enhance the international visibility of their research. Through its activities in applied research and technology transfer, LIST aims to support all companies – whether large groups or small to medium-sized enterprises (SMEs) – in their innovation projects. The Institute also contributes to the establishment of new companies in Luxembourg by developing innovative technology and expertise. Finally, it offers scientific support to national policy making.

LIST works across the entire innovation chain, including development of fundamental and applied scientific research, knowledge and competences; experimental development, incubation and transfer of new technologies, competences, products, and services; scientific policy support to the Luxembourg government, businesses and society in general; and doctoral and post-doctoral training, in partnership with universities.

LIST works in partnership with other RTOs, universities, large industrial groups, SMEs and public bodies across a range of sectors, including manufacturing, construction, logistics and mobility, eco-technology, space, IT services, and the public and healthcare sectors. Partnerships can take several forms: collaborative research (with joint financial involvement and risk-taking, and shared results); contract research (aimed at both SMEs that lack the resources required to conduct research and large corporate groups that wish to outsource part of their R&D and innovation activities while retaining ownership of the results); hosting of researchers within the framework of public-private partnerships (P/PPs) (making LIST staff available to companies and vice versa); and provision of services (providing access to LIST technology platforms to carry out research and innovation projects).

LIST conducts its research activities within three departments:

- **Environmental Research and Innovation** develops strategies, technologies and tools to better monitor, assess, use and safeguard natural and renewable resources. Its mission is to implement a smart green vision, creating better understanding of complex environmental and biological systems and their interaction with the technosphere, in order to accelerate innovation towards sustainable management of natural resources and the transition towards a circular economy.
- **IT for Innovative Services** focuses its research around innovation in services with a high level of information intensity. It focuses on "big data" operational issues for decision-making, use of information systems in measuring and controlling the quality of services, and tools for innovation processes in IT services. It co-operates directly with market stakeholders within the framework of an open innovation approach and implementation of a "living lab" associating all stakeholders in service design and roll-out. The department is active in several sectors, including construction, logistics and mobility, healthcare and IT.
- **Materials Research and Technology** aims to translate cutting-edge materials research into applicable technology by engaging in close relationships and joint projects with both academic and industrial partners. Its research and technology activities target two main areas: nanomaterials and nanotechnology, and composite materials. Its experts – who come from academic institutions, RTOs and industry and include chemists, physicists, materials and engineering scientists, and increasingly life scientists – work on an interdisciplinary basis, both within the LIST departments and with actors from the Luxembourg public or private ecosystem.

Source: LIST website (www.list.lu).

Box 3.5. The Luxembourg Institute of Health (LIH)

LIH (formerly CRP Santé) is Luxembourg's leading public organisation for basic, pre-clinical and clinical research in life sciences. It performs research and carries out studies in clinically oriented biomedical research (oncology, infection and immunity, immunology and cardiovascular diseases) and public health. It works with health-sector stakeholders, including hospitals and public and private biomedical organisations, at both the local and international levels. It carries out its research activities within five research departments:

- **Translational Cardiovascular Research** focuses on understanding the mechanisms responsible for the development of heart failure. It works in close collaboration with the Centre hospitalier de Luxembourg (CHL) and the National Institute of Cardiac Surgery and Interventional Cardiology.
- **Immunology** has a broad field of interest, from basic research to contract R&D for the diagnostic and vaccine industry. It is a partnership with the Laboratoire national de santé.
- **Oncology** focuses on experimental cancer research with a strong translational profile and the potential to develop into a clinical outcome. It closely collaborates with CHL.
- **Public Health** provides information on the population's state of health, advises public authorities on healthcare projects and their evaluation, and carries out economic analysis of the healthcare system. It is also home to two Luxembourg National Focal Points: the European Medicines Agency and the European Monitoring Centre for Drugs and Drug Addiction.
- **Infection and Immunity** has two laboratories that perform fundamental and applied research in the fields of chronic viral infections and allergic and immune-mediated diseases.

These thematic research departments are supported by three competence centres: Luxembourg Biomedical Research Resources, the Competence Centre for Methodology and Statistics and the Clinical and Epidemiological Investigation Centre. The competence centres provide services to internal customers, public organisations and private partners. LIH also has a technology transfer office whose mission is to help commercialise research results. It works to identify inventions with commercial potential, assists with securing the necessary property rights and helps to market new technologies by collaborating with industry and creating start-ups.

Since 2015, the Integrated BioBank of Luxembourg (IBBL) has merged with LIH. IBBL retains extensive autonomy and its own multiannual performance contract under this arrangement, while working under the supervision of the LIH board of administration. Its integration into LIH aims to help create synergies in financial, administrative and technical matters, including in terms of sample storage to meet the needs of national research actors. The arrangements also guarantee IBBL the independence necessary to carry out its national and international activities. Chapter 4 discusses IBBL more extensively.

Source: LIH website (www.lih.lu).

While the University has displaced the CRPs as the largest public-sector research performer in Luxembourg, the CRPs have also expanded significantly over the last 15 years, thanks to a significant increase in public investment that has led to a large influx of new researchers. This expansion has gone hand in hand with a broadening of the missions of CRPs: while they were originally established to support service-oriented applied research to meet business-sector needs, CRPs have increasingly focused on more strategic applied (and occasionally oriented basic) research. The new CRP law confirms this positioning: while CRPs should continue to focus on research, development and innovation

to promote knowledge and technology transfer, they may occasionally undertake oriented basic research. Furthermore, they may engage in technological development to support product development, production processes and services. In this context, the law envisages scientific and technological co-operation at the national and international level. It also gives increased weight to valorisation activities, including through creating spin-off firms, to foster new economic activities in Luxembourg. Finally, the law explicitly calls on the CRPs to encourage researcher mobility and contribute to training research personnel, including by supervising doctoral candidates (in collaboration with the University of Luxembourg or other universities) and participating in doctoral schools.

Box 3.6. **The Luxembourg Institute of Socio-Economic Research (LISER)**

LISER (formerly CEPS/INSTEAD) is a public research centre active in the fields of social and economic policy. It covers topics such as poverty, inequality, education, social inclusion, employment, unemployment, health, housing, mobility and regional convergence. Its mission is to produce relevant insights for social and economic policy based on empirical evidence, in order to improve the understanding of causal relationships and provide sound evidence on the impact of institutional settings and policy options. It organises its research activities around three research departments:

- **Labour Market** primarily addresses the process of labour-income determination, both from a worker's perspective and from the perspective of companies and employers.
- **Living Conditions** focuses on the social aspects of income and wealth distribution.
- **Urban Development and Mobility** focuses on the spatial dimension of social and economic policy.

The institute also includes a transversal co-ordination unit that has two main tasks: providing common services across departments (e.g. survey data collection, and social and economic indicator provision); and creating synergies across departments through co-operation based on common methodology or overarching topics.

Source: LISER website (www.liser.lu).

These sorts of changes are far from unique to Luxembourg. In many OECD countries, the role of mission-oriented, applied research-intensive PRIs has shifted from performing purely applied and industry-oriented research to becoming increasingly involved in basic research activities and projects (see Box 3.7). In addition, PRIs have rebalanced their R&D personnel to include a greater number of researchers. At the same time, universities often perform applied research and increasingly co-operate with the business sector. This leads to significant overlaps between the missions and tasks of PRIs and universities, with the potential of increasing both competition and co-operation between them. The presence of similar dynamics in Luxembourg leads to some questioning about the roles of CRPs. In some respects, the CRPs serve considerably different functions than the University of Luxembourg. For instance, providing support to evidence-based policy features prominently in the mission of both LISER and LIST (which also has the explicit objective of strengthening business-innovation capacities), but these types of activities are notoriously difficult to measure and account for using rigorous performance indicators.

Box 3.7. **Public research institutes (PRIs) in OECD countries**

PRIs play an important role in national innovation systems. Together with universities, they are the main public research actors and an important tool for governments seeking to promote research and innovation (OECD, 2011). PRIs are key actors, not only within national boundaries but also in international networks. In Europe, PRIs are important nodes in the innovation and research networks created by European programmes (Technopolis, 2010). The mission of PRIs is to provide R&D, technology and innovation services to companies, governments and, more generally, society. In this respect, they distinguish themselves from universities, whose main mission is to educate students.

Different national innovation systems and historical or socio-economic contexts have shaped the process through which PRIs were established. In Europe, many PRIs were created after the Second World War to support industrial and technological development (Leijten, 2007). In some cases, PRIs (e.g. PERA, the former Production Engineering Research Association, in the UK or some parts of SWEREA in Sweden) originated from research associations that were originally established to solve practical problems in some industries and then were institutionalised in the form of institutes. In other cases, PRIs (e.g. SINTEF in Norway or the Fraunhofer Institutes in Germany) were created with the specific goal of promoting industrial development. In some countries, PRIs were established as institutes providing services such as measurement, testing and certification, generally transitioning over time towards more science and research-intensive organisations. For example, VTT in Finland was originally conceived as a service-based organisation, but has morphed into an organisation promoting industrial development in the country (Technopolis, 2010).

Because of the multiple rationales and historical paths that led to their creation, PRIs today have extremely diversified functions (Technopolis, 2010) and funding, as detailed below:

- Some PRIs are scientific research institutes that largely perform the same kind of research as universities. PRIs of this kind generally get a large part of their funds through block grants. Examples are the Max Planck Institutes in Germany or the Centre national de la recherche scientifique in France.
- A second category of PRIs consists of government laboratories that provide services and information to governments. They include institutes performing applied mission-oriented research around different technologies, such as energy technologies, biotechnologies and telecommunications. They generally belong to the ministries responsible for policy initiatives in their domain of research. LISER and, to some extent, LIH fall into this category.
- A third category of PRI comprises applied research institutes focusing on research to solve practical problems or challenges for the benefit of society or some actors in the innovation system, typically private companies (also known as RTOs). These PRIs generally obtain part of their income through government block funding and the remainder through contractual research projects financed by the business sector. For example, the Fraunhofer Institutes in Germany, TNO in the Netherlands or VTT in Finland generally manage to attract more than half of their funding from the market.

It should be noted that many PRIs perform several functions simultaneously. Other tasks associated with PRIs include preserving, storing and ensuring access to knowledge and scientific data through libraries, datasets and repositories, or providing major scientific infrastructure and facilities (e.g. satellites, telescopes).

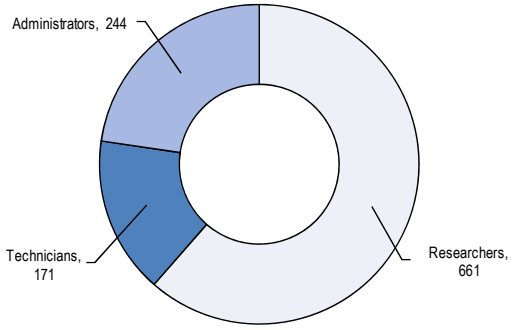
Since the Luxembourg CRP name changes and merger are very recent, all available data refers to their pre-2015 status. For this reason, the remainder of this chapter uses the former names of the CRPs.

CRP staff

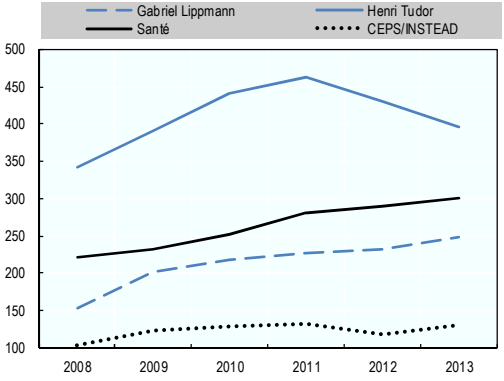
The CRPs employed 1 076 staff in 2013 – more than three-quarters of whom were researchers or technicians (Figure 3.16, Panel a). This is up from 819 staff in 2008, but down from a peak of 1 101 in 2011. The recent decline is solely due to changes in what used to be the largest CRP, Henri Tudor, where staff numbers decreased from 462 in 2011 to 396 in 2013 (Figure 3.16, Panel b). Most of the decline owes to a fall in the number of researchers, from 311 in 2011 to 256 in 2013 (Figure 3.16, Panel c). Almost 39% of CRP researchers are female, though gender composition varies considerably among CRPs, reflecting the traditional disciplinary gender imbalances seen in most countries (Figure 3.16, Panel d).

Figure 3.16. **CRP staff profiles (based on headcounts)**

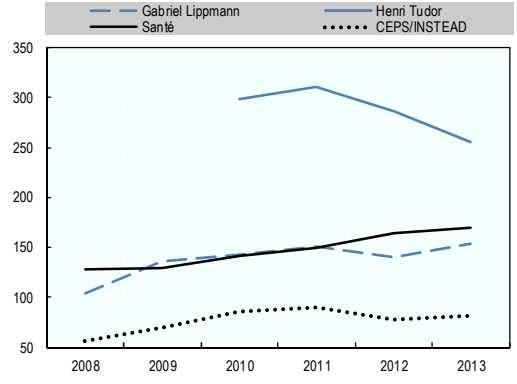
Panel a: Professions of CRP staff, 2013



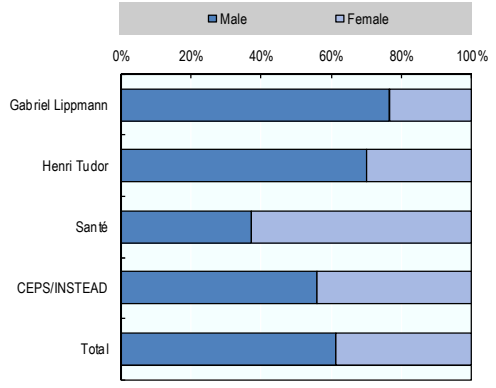
Panel b: Evolution in CRP total staff numbers



Panel c: Evolution in CRP researcher numbers



Panel d: Gender balance of researchers, 2013

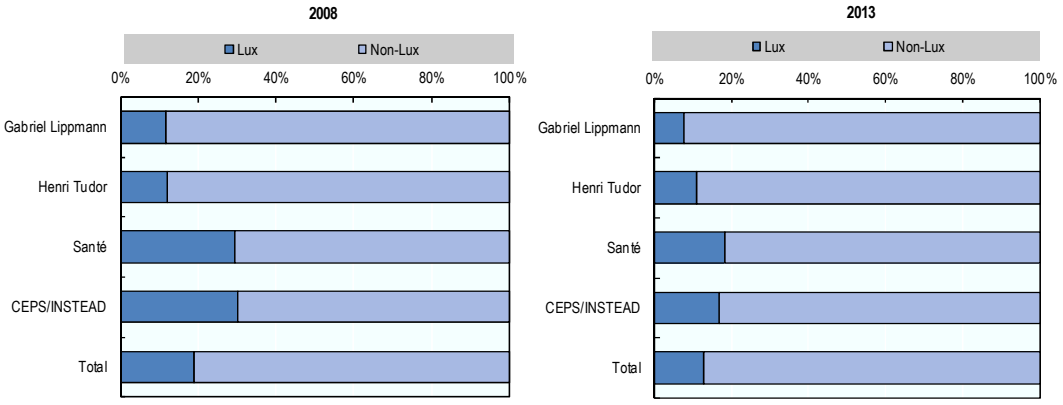


Source: Ministry of Higher Education and Research (2014), *Rapport d'Activité 2013*.

Much of the recent expansion in CRP researcher numbers has been fuelled by the hiring of non-Luxembourgers. Reflecting Luxembourg's small size and openness, a remarkable 87% of CRP researchers are foreigners, up from 81% in 2008 (Figure 3.17). The largest changes have taken place at CRP Santé – up from 71% of foreign researchers in 2008 to 82% in 2013 – and CEPS/INSTEAD – up from 70% in 2008 to 83% in 2013. Most of the foreign researchers are from neighbouring countries, particularly France – which accounted for 46% of researchers at CRP Henri Tudor and 36% at CRP Santé

in 2013. However, increasing numbers of foreign researchers are coming in from further afield. In this regard, the CRPs have benefitted from the PEARL and ATTRACT programmes of the FNR to attract – though only to a minor extent – top international talent to Luxembourg. Chapter 4 discusses these programmes.

Figure 3.17. **Proportions of foreign and national staff in the CRPs (based on headcounts)**

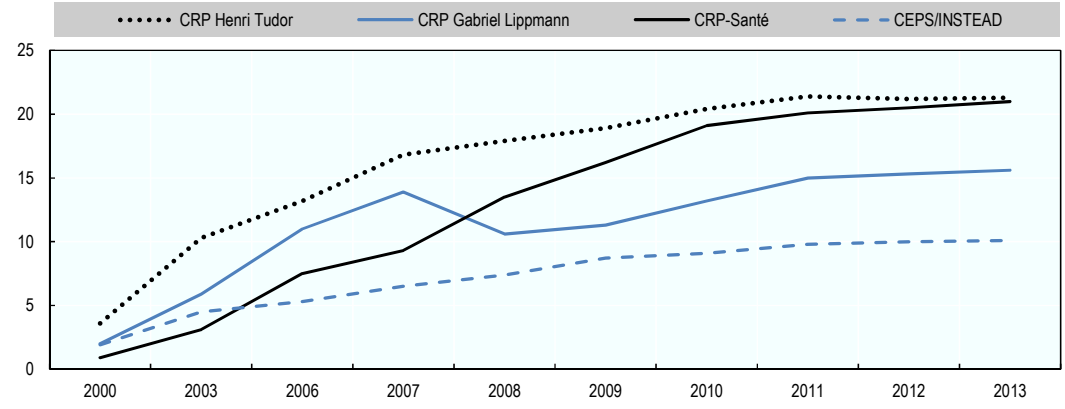


Source: Ministry of Higher Education and Research (2014), *Rapport d'Activité 2013*.

Research funding

The growth of CRPs owes to generous increases in public funding for the CRPs – the value of block grants from the Ministry of Higher Education and Research increased from EUR 8.4 million in 2000 to EUR 68.0 million in 2013 (Figure 3.18). Most of the increases occurred in the 2010s; in fact, since 2011, the value of block grants has remained more or less static. Some CRPs have benefitted more from these increases than others, e.g. CRP Santé saw its block grant grow from EUR 0.9 million in 2000 to EUR 19.1 million in 2010, while CEP/INSTEAD saw its block grant grow from EUR 1.9 million to EUR 9.1 million over the same 10-year period. The proportion of block grants in CRP revenues varies slightly among institutes and has mostly declined slightly in recent years: block grants accounted for 63% of CRP revenues in 2013, down from 65% in 2008 (Figure 3.19).

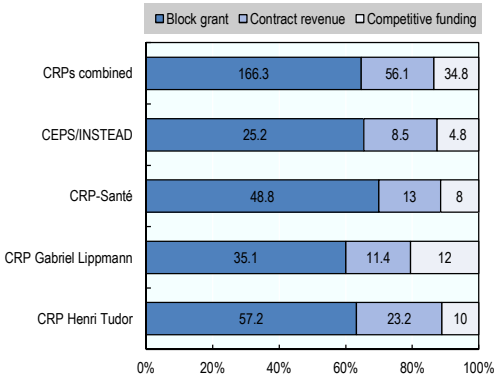
Figure 3.18. **Evolution of block grant in the CRPs, 2000-13 (MEUR)**



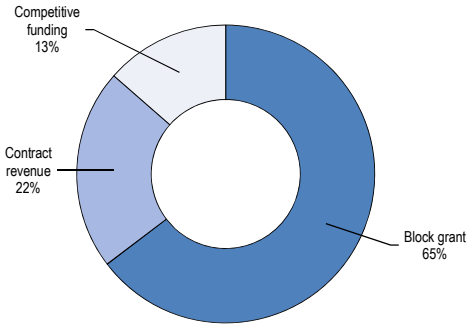
Source: Rieder et al. (2014), *The Luxembourg Innovation System*.

Figure 3.19. **CRP revenues**

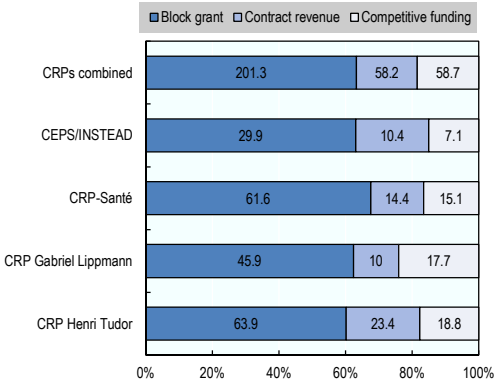
Panel a: Breakdown of revenues by CRP, 2008-10 (MEUR)



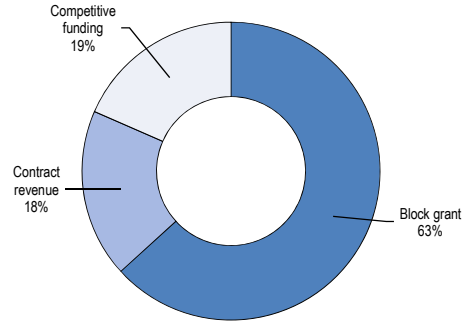
Panel b: Percentage breakdown of revenues of all CRPs combined, 2008-10



Panel c: Breakdown of revenues by CRP, 2011-13 (MEUR)

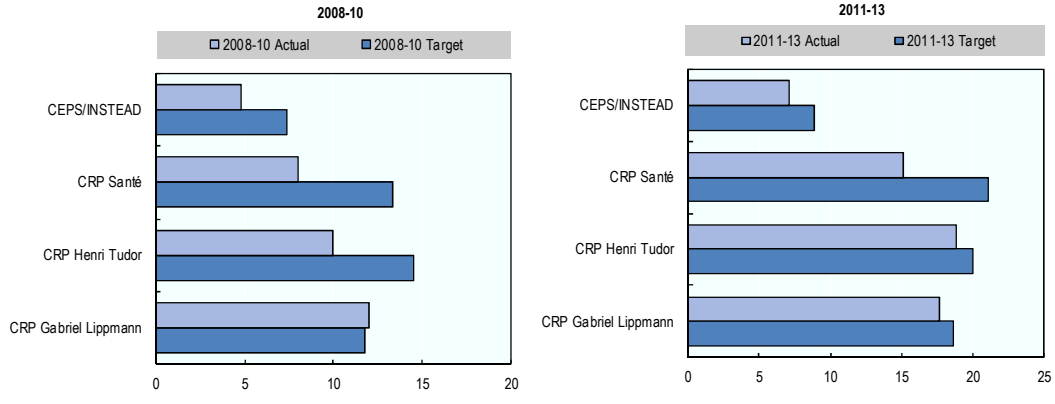


Panel d: Percentage breakdown of revenues of all CRPs combined, 2011-13



Source: Rieder et al. (2014), *The Luxembourg Innovation System*.

Figure 3.20. **Competitive research revenues in the CRPs (MEUR)**

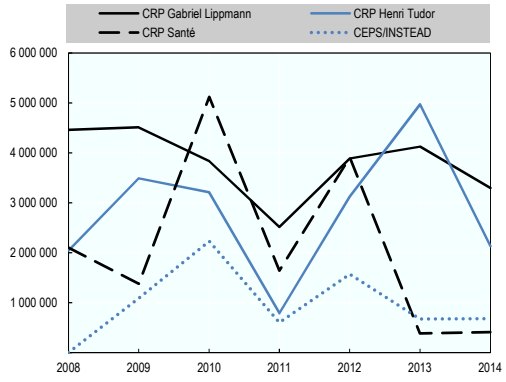


Source: Rieder et al. (2014), *The Luxembourg Innovation System*.

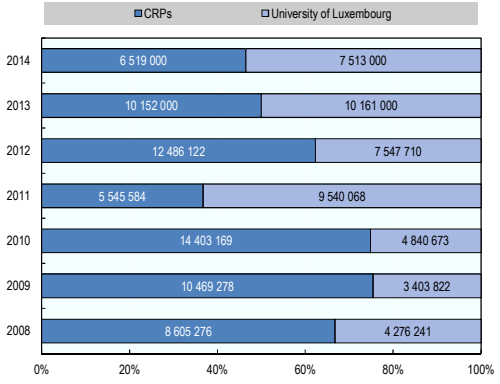
Competitive funding – obtained chiefly from the FNR and, to a lesser extent, the European Union – accounts for an increasing share of CRP revenues (Figure 3.19). In the most recent three-year performance contract period 2011-13, the CRPs attracted EUR 58.7 million (19% of their revenues) in competitive funding, compared to EUR 34.8 million (13% of revenues) for the previous performance contract period 2008-10. The share of revenue from competitive funding varies by institute, standing for example at 24% in 2011-13 for CRP Gabriel Lippmann and 15% for CEPS/INSTEAD. While the growth of competitive funding in CRP revenues is a promising development, it still falls short of government expectations: the CRPs have almost always missed their performance targets for competitive funding – although to a lesser degree in 2011-13 (Figure 3.20). In many OECD countries, it is not unusual for CRP-type institutes to obtain around one-third of their revenues through competitive funding.

Figure 3.21. **FNR CORE Programme funding**

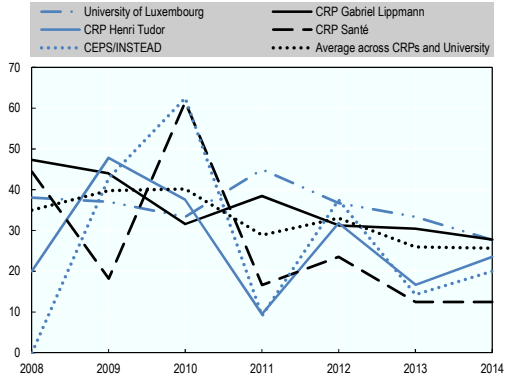
Panel a: FNR financial contribution to the CRPs through the CORE programme



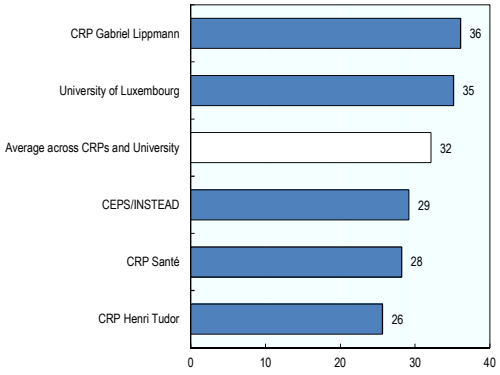
Panel b: Comparison of FNR CORE programme funding for the CRPs and University of Luxembourg



Panel c: Success rates in FNR CORE programme (2008-14), by research performer



Panel d: Average success rates in FNR CORE programme (2008-14), by research performer



Source: FNR (2015), personal communication.

The CRPs together received about 10% of European 7th Framework Programme funding allotted to Luxembourg up to August 2014 – approximately half of the funding received by the University of Luxembourg over the same period. This disappointing performance contributes to the CRPs missing their competitive-funding performance targets. The FNR, primarily through its CORE programme, accounts for the bulk of competitive funding

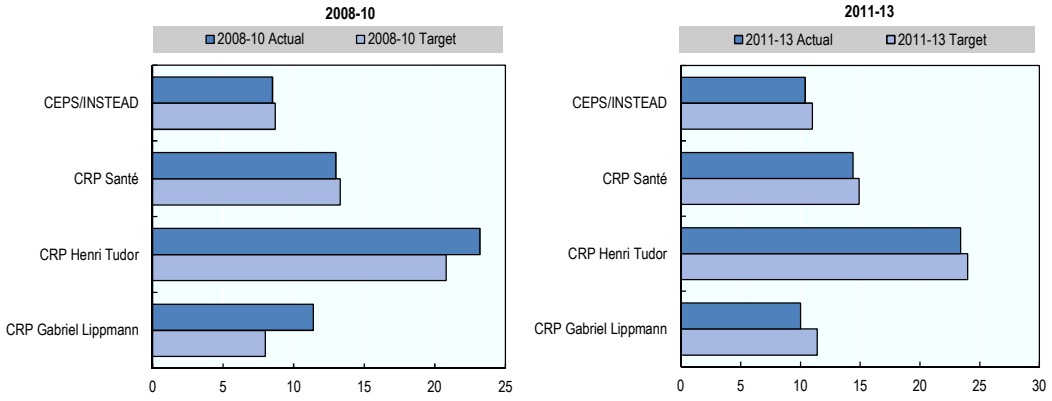
obtained by the CRPs. The amount of funding flowing from the FNR to the CRPs fluctuates considerably from one year to the next, partly on account of small numbers, though CRP Gabriel Lippmann has done consistently well (Figure 3.21, Panel a). The University's growth in recent years – particularly its increasing research intensity through the interdisciplinary centres – has increased competition for FNR funding, which has had an impact on the amounts of funding flowing to the CRPs (Figure 3.21, Panel b). This is reflected in the gradual decline in success rates for grant applications in recent years (Figure 3.21, Panel c), though the situation varies by institute: CRP Gabriel Lippmann had the highest success rate (36%) and CRP Henri Tudor the lowest (26%) among the main research performers in Luxembourg in 2008-14 (Figure 3.21, Panel d); CRP Santé has been particularly unsuccessful in the last couple of years in securing FNR funding. Some CRPs, e.g. Henri Tudor, complain that the sole focus of the FNR on scientific excellence discriminates against other types of excellence; they have repeatedly called on the government to set up new competitive-funding instruments for innovation and technology transfer, as is the case in some other OECD countries. To some extent, provisions in the 2009 law on research, development and innovation, an initiative of the Ministry of the Economy, aim to include funding of collaborative research between business and public research organisations, including the CRPs and University, without the stringent scientific excellence criteria applied by the FNR. However, uptake of this funding until now has been disappointing. Chapter 4 discusses this initiative.

The other major component of revenues for the CRPs is contract research funding, primarily from government departments and businesses. The CRPs attracted EUR 58.2 million (i.e. 18% of their revenues) in contract research funding in the three-year performance contract period 2011-13, compared to EUR 56.1 million (22% of revenues) for the previous performance contract period 2008-10 (Figure 3.19). The share of revenue from contract research funding (e.g. 22% for CRP Henri Tudor and 14% for CRP Gabriel Lippmann in 2011-13) varies by institute. While its relative decline is perhaps more a reflection of growth in other funding streams, all CRPs failed to meet their related performance targets in 2011-13 (Figure 3.22), owing to economic difficulties in the business sector and increasing competition from the University. Still, the proportion of business funding of government intramural expenditure on R&D (GOVERD) in Luxembourg – essentially the R&D performed by the CRP sector as a whole – stood at 6% in 2012, comparing favourably to the 3.5% OECD average (Figure 3.23).

Research outputs

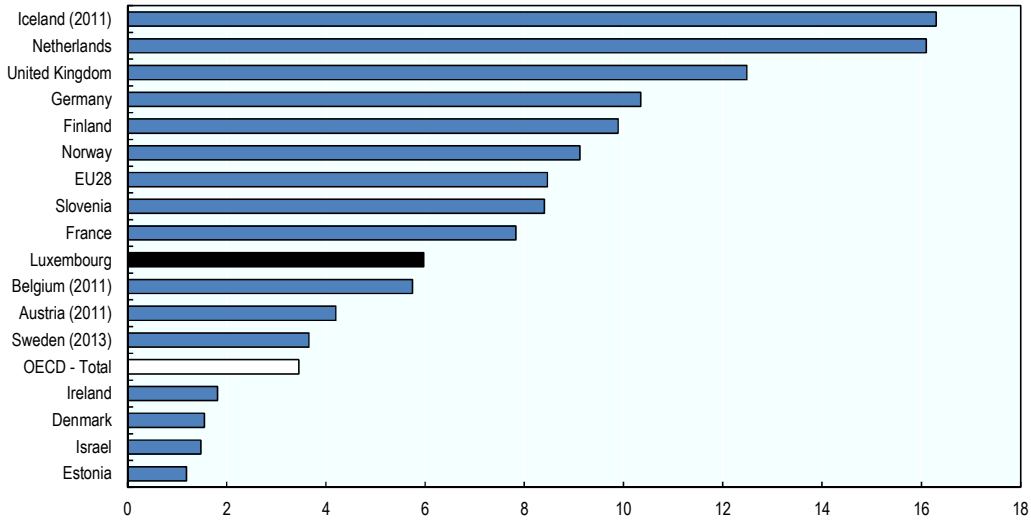
Contract research is perhaps the most visible channel through which the CRPs are believed to contribute to Luxembourg's economy and society, but other channels should not be overlooked. For example, much competitive research funding obtained through the European Union and FNR involves partnering with industry and public policy actors in knowledge co-production. The CRPs are also expected to disseminate their research findings through scientific publications. Bibliometric indicators reveal that all the CRPs (except for CRP Santé) reached, or were very close to reaching, the publication-related targets featured in the performance contracts (Table 3.6). While all CRPs have increased the number of scientific outputs, the impact and number of citations of these publications – especially for CEPS/INSTEAD and CRP Henri Tudor – are not exhibiting similar growth.

Figure 3.22. **Contract research revenues in the CRPs (MEUR)**



Source: Rieder et al. (2014), *The Luxembourg Innovation System*.

Figure 3.23. **Percentage of GOVERD financed by industry (2012)**



Note: Data for the private non-profit sector are included in the government sector for Germany and the Netherlands.

Source: OECD (2015), *OECD Main Science and Technology Indicators* (database), http://dotstat.oecd.org.

Luxembourg's CRPs have become increasingly active in patenting, licensing and spin-off creation – related targets are set in their performance contracts – and have recently set up technology transfer offices to support these activities. Table 3.7 shows the CRPs were able to surpass their targets on patenting, but had more difficulties creating spin-off firms.

Table 3.6. **Publications of the CRPs and CEPS/INSTEAD, 2011-13**

	2011		2012		2013		2011–13	
	Target	Actual	Target	Actual	Target	Actual	**Target**	**Actual**
CRP Henri Tudor								
Publications with impact factor (IF)>=2	20	51	50	84	50	55	**120**	**190**
Publication intensity referenced by Thomson or Scopus	0.3	0.55	0.55	0.52	0.55	0.56		
Publication intensity (publication/researcher)	0.50	0.82	0.80	0.79	0.80	0.86		
CRP Gabriel Lippmann								
Publications IF>=2	x	x	x	x	x	x	**100**	**261**
Publication intensity referenced by Thomson or Scopus	0.80	0.95	0.85	0.99	0.85	1.31		
Publication intensity (publication/researcher)	0.90	1.18	1.00	1.12	1.0	1.40		
CRP-Santé								
Publications in journals with IF (Thomson) >5	30	21	30	30	30	32	**90**	**83**
Publications in journals with IF (Thomson) >10	7	3	7	2	7	6	**21**	**11**
Referenced publication intensity [publication (IF > 2)/researcher]	0.70	0.64	0.70	0.72	0.70	0.65		
CEPS/INSTEAD								
Publications in peer-reviewed journals	--	84	--	115	--	78	**124**	**277**
Publication intensity (ISI, SCOPUS, AERES)	0.7	0.43	0.7	0.71	0.7	0.45	**--**	**--**
Organised International Conferences (>60 participating experts)	--	2	--	4	--	2	**5**	**8**
Scientific conference presentations as keynote speaker, session chairman, etc.	--	27	--	22	--	39	**30**	**88**
Co-publications with visiting scientists	--	4	--	11	--	6	**>20**	**21**

Note: x = not applicable.

Source: Rieder et al. (2014), *The Luxembourg Innovation System*.

Table 3.7. **Numbers of patents, licences, spin-offs and prototypes in the CRPs, 2011-13**

		Target	Actual
CRP Henri Tudor	Patents	8	9
	Paid licences	50	213
	Spin-offs	4	3
CRP Gabriel Lippmann	Patents	12	22
	Paid licences	12	5
	Free licences	18	8
	Spin-offs	2	1
	Prototypes and processes	15	26
CRP-Santé	Patents	3	3
	Spin-offs	1	0

Source: Rieder et al. (2014), *The Luxembourg Innovation System*.

Development of human skills is an often overlooked yet critical contribution of public-sector research to the economy and society; an important component in the CRP context is doctoral training. CRP performance contracts include performance targets on numbers of PhD students and thesis submissions, which the CRPs are more or less able to meet (Table 3.8). The majority of PhD students are registered at universities outside of Luxembourg. The CRPs have secured a sizeable number of the Aides à la formation recherche (AFR) doctoral and post-doctoral grants provided through the FNR, though numbers have sharply declined in recent years as more grants have gone to the University (Figure 3.24).

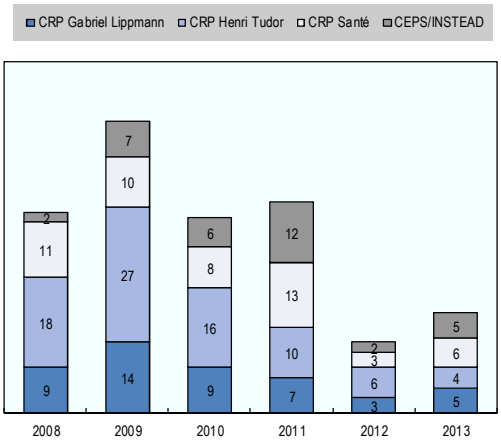
Table 3.8. **Number of doctorates in the CRPs and CEPS/INSTEAD, 2011-13**

	2011		2012		2013		2011-13	
	Target	Actual	Target	Actual	Target	Actual	**Target**	**Actual**
CRP Henri Tudor								
PhD students	44	56	45	49	45	37		
PhD thesis							**30**	**40**
CRP Gabriel Lippmann								
PhD students	35	35	36	39	37	46		
PhD thesis	-	-	-	-	-	-	**25**	**17**
CRP-Santé								
PhD students							**35**	**31**
PhD thesis							**25**	**25**
CEPS/INSTEAD								
PhD students	14	17	16	18	18	21		
PhD thesis		1		2		5	**11**	**8**

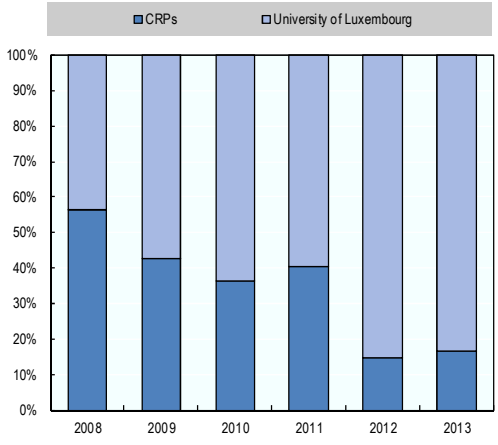
Source: Rieder et al. (2014), *The Luxembourg Innovation System*.

Figure 3.24. **FNR AFR grants, 2008-13**

Panel a: Number of FNR AFR grants awarded to the CRPs, by institute



Panel b: Comparison of number of FNR AFR grants awarded to the CRPs and University of Luxembourg



Source: FNR (2015), personal communication.

Evaluation of the CRPs

Between 2010 and 2012, several research units in the CRPs were individually evaluated by peer-review panels:[1]

- CRP Henri Tudor: Advanced Materials and Structures; Resource Centre for Environmental Technologies; Service Science and Innovation Department
- CRP Gabriel Lippmann: Science and Analysis of Materials Department; Geohydrosystems and land-use management and Aquatic and terrestrial ecosystems units at the Environment and Agro-Biotechnologies Department; Informatics, Systems and Collaboration Department

- CRP Santé: Department of Oncology; Laboratory of Cardiovascular Research; Public Health Research Department
- CEPS/INSTEAD: Population and Employment (in conjunction with the IRISS and RelEx units); Geography and Development.

It is important to note that evaluations have not been carried out at the level of the whole CRP, but only of individual research units. Furthermore, the 2010-12 round of evaluations did not cover all the CRP research units – the remaining units will be assessed in future rounds of peer-panel evaluation. Evaluation findings vary considerably among research units, even within the same CRP. In fact, more variation sometimes occurs between units in the same CRP than between units in different CRPs. Overall, the evaluations identify many positive features, e.g. a strong focus on industrial collaboration, some good scientific outputs, well-equipped research facilities, good support for PhD students and some strong research links with foreign universities. They also highlight several problems, in particular:

- *A lack of research focus and strategy*: the research priorities set by some research units can be too diverse, and research agendas are insufficiently focused. The evaluations found that the units that performed better in attracting funding and producing scientific publications were more likely to have developed a clear vision of their strategic research priorities.
- *Weak co-operation with other research-performing actors*: there is often underexploited potential to co-operate with other research units in the same CRP, as well as with units in other CRPs and the University of Luxembourg.
- *Mixed results in scientific outputs*: international visibility of CRP research, and the number of publications in highly ranked journal, are often rather low. The evaluations showed that some research units had successfully transitioned towards more research-oriented activities. These units focused their research on specific scientific questions of particular interest to their mission, increased the number of scientific publications and attracted research funding from the FNR and European Union. Other research units were still struggling to reorient their activities towards a more scientific approach.
- *Weak performance in obtaining EU funding*: all the evaluations identified low EU funding performance as a common weakness.

While the evidence presented earlier in this section mostly aligns with these findings, it also suggests some developments in the right direction: CRPs are obtaining an increasing proportion of their research revenue through competitive funding and have improved their scientific-publication record, thanks in part to recent success in attracting good international researchers. Still, CRPs continue to face some important challenges.

First, they need to improve the strategic prioritisation of their research and other activities – which is a challenge, because clients' often short-term industrial and policy needs have traditionally had a strong influence on CRP agendas, limiting their ambition and geographical scope. Further, the legacy of opportunistic (rather than strategic) growth of the CRPs and their research units in earlier periods has sometimes left them with a diverse array of research activities and support services that are difficult to organise strategically. The success of the University's SnT interdisciplinary centre in securing long-term industry funding through its Partnership Programme – which allows it to adopt a more strategic approach to its research – could provide useful lessons for the CRPs.

Some elements of this approach are already in evidence in the CRPs – by way of example, Box 3.8 presents recent strategic developments at CRP Henri Tudor. SnT has also developed approaches for resolving tensions between academic and user-oriented research in the same institute. The CRPs could also apply these approaches, while taking into account their somewhat different missions, histories and legacies.

Box 3.8. **Towards strategic development of markets and partnerships: The case of CRP Henri Tudor**

In 2011, CRP Henri Tudor introduced a new method for managing its research activities through so-called "innovation programmes". These programmes aim to provide a multidisciplinary response to the innovation challenges of nine markets: manufacturing, construction, eco-technologies, mobility, transport and logistics, healthcare, public services, regulated IT services for the financial sector and human capital. They are credited with making CRP Henri Tudor's offerings more understandable and therefore more accessible to its business and policy partners.

In parallel, CRP Henri Tudor also set up a professional management approach for its partners/clients. For some partners, the potential of partnerships was such that it proved useful to develop partnership formulas along the lines of "key accounts". Partnership framework contracts – with the goal of working in a long-term P/PP on an agreed portfolio of multiannual research activities – have been signed with companies such as Paul Wurth in 2011, PSA Peugeot Citroën in 2012, ArcelorMittal and ILNAS in 2013, and EBRC and POST Luxembourg in 2014.

Source: CRP Henri Tudor (2014), *Annual Report 2013*, www.innovation.public.lu/fr/brochures-rapports/r/ra-crpht-2013/ra-tudor-en-2013.pdf.

Second, promoting the international focus of the CRPs, e.g. by encouraging greater participation in EU funding programmes and greater co-operation with firms outside of Luxembourg, could also contribute greatly to improving international scientific excellence in a framework of socio-economic relevance. The main area of CRP activities remains the Grande Région. Extending co-operation beyond the region – with firms and other research actors in other parts of Europe and the rest of the world – will require raising the level of ambition of research and increasing its international visibility.

A third challenge is to overcome the continued weak co-operation among Luxembourg's public research actors. The merger of CRP Gabriel Lippmann and CRP Henri Tudor into LIST seems appropriate in this regard, particularly given their strongly overlapping research areas. Further mergers – e.g. of LIH and LISER with either the University or LIST – would require considerable time to prepare and should be carefully evaluated, taking into account the relative merits of grouping researchers, creating critical mass and reducing administrative costs. Nevertheless, the CRPs and the University could significantly enhance their interaction. For example, very few of the PhD students at the CRPs are registered at the University, and joint staff appointments are extremely rare. Various institutional arrangements at the University that appear to hinder greater co-operation are currently under review or revision; co-location at Belval is likely to offer new opportunities for closer collaboration (see Chapter 4). Luxembourg could learn from experiences in many advanced European countries, where deep and extensive ties exist between universities and CRP-like public research institutes (see Box 3.9). In particular, joint senior staff appointments, PhD supervision and research projects between the University of Luxembourg and CRPs would help build and cement co-operation between the two.

Box 3.9. **Linkages between PRIs and universities in selected OECD countries**

In many OECD countries, PRIs are increasingly conducting joint research and innovation activities with universities (Technopolis, 2010). Co-operation between the two types of organisations benefits their research activities: universities bring to the table their expertise in fundamental research and education, while PRIs provide knowledge on applied research, technical know-how and infrastructure. Co-operation between PRIs and universities takes place in different ways depending on the different contexts and institutional settings. Personal relationships among researchers with different affiliations also play a role. Examples of linkages include the following:

- *Linkages driven by participation in **joint research projects***. Joint research projects between universities and PRIs are the most common and widespread means of co-operation. PRIs increasingly participate in national and international research projects involving one or more universities, which generally lead to joint scientific publications. For example, by the early 2000s more than half of the scientific publications produced by Norwegian PRIs were co-authored with universities; in 2008, Swedish PRIs spent approximately 21% of their core funding on joint projects with universities (Technopolis, 2010); VTT (the Technical Research Centre of Finland) regularly conducts joint research projects with Finnish universities; and the Fraunhofer Institute for Reliability and Microintegration (Fraunhofer IZM) has a long list of university research partners in many Germans cities, as well as in Italy, Spain, the Netherlands, Finland, Japan, Sweden and the United Kingdom (Fraunhofer IZM, 2014).

- *Linkages driven by **joint appointments of research staff***. Another factor fostering the establishment of knowledge linkages is the joint recruitment of human resources for science and research. For example, the directors of the Fraunhofer institutes also work as professors at a nearby university; not only does this foster joint project development, it also facilitates organising internships between Fraunhofer institutes and universities, and recruiting PhDs. The largest Norwegian research institute – the Foundation for Scientific and Industrial Research (SINTEF) – and the Norwegian University of Science and Technology share more than 500 R&D personnel (approximately 25% of SINTEF staff) (OECD, 2008b). Joint affiliation of researchers at both universities and PRIs is also common practice in Italy and France.

- *Linkages driven by **joint supervision of PhD students or post-doctoral researchers***. In those areas where clear synergies and research overlaps exist, joint supervision of PhD students or young post-doctoral researchers is a way to strengthen joint co-operation and research linkages. For instance, students enrolled in PhD programmes at the Swiss Federal Institute of Technology Zurich (ETH Zurich) can carry out their doctoral thesis research either at ETH Zurich or at one of the research institutes in the ETH Domain. Joint PRI/university supervision of PhDs and post-doctoral researchers is also common practice in other OECD countries, such as Norway and Germany.

- *Linkages driven by **joint provision of education courses***, including higher education courses and lifelong learning. Germany offers interesting examples of these practices: Fraunhofer IZM supports teaching at the Technical University of Berlin by offering students additional seminars and the opportunity to participate in national and international research projects. The Fraunhofer Academy is the Fraunhofer Institutes' provider of lifelong learning and part-time training for specialists and managers. It offers classes and seminars in co-operation with universities. Fraunhofer Institutes contribute by providing practical experience and knowledge around applied research, while universities provide interdisciplinary knowledge.

Box 3.9. **Linkages between PRIs and universities in selected OECD countries** (*continued*)

- *Linkages driven by **joint use of research facilities** or the creation of joint research labs*. Some institutions have created joint research campuses and laboratories where researchers affiliated with universities or PRIs can use research equipment, run experiments and generally work together on joint research activities. These are located within the university campus or PRI; alternatively, they are part of larger science and technology parks or innovation clusters. In Norway, the SINTEF headquarters are located on the campus of the Norwegian University of Science and Technology (NTNU) in Trondheim, with the two organisations sharing many research facilities. SINTEF has also strengthened its linkages with the University of Oslo by setting up three joint research centres, on applied mathematics, materials technologies and nanotechnologies. In Finland, VTT and the University of Oulu, together with partners in the business sector, are currently building a 5G Test Network to advance research in the field of wireless communications. In other cases, VTT researchers are hosted by Finnish universities. For instance, the VTT research group on Separation Technology will be located within the Department of Chemistry of the Lappeenranta University of Technology. In Switzerland, competence centres to promote cross-disciplinary research between the ETH Federal Institutes of Technology (ETH Zurich and EPFL Lausanne) and the ETH Domain research institutes have been established.
- *Linkages driven by **shared governing mechanisms***. Shared institutional mechanisms that formally govern co-ordination between PRIs and universities are less common. In Switzerland, ETH Zurich and EPFL Lausanne and four associated research institutes are part of the so-called ETH Domain (ETH Domain, 2014). The ETH Board, which brings together individuals from politics, industry and society, steers and provides strategic management of the ETH Domain as a whole. This translates into common strategic objectives across ETH Domain organisations, including providing education to students and permanent lifelong learning to citizens; conducting joint research; providing scientific and technical services; and promoting international co-operation. Other examples of governing mechanisms to steer strategic co-operation between PRIs and universities can be found at the institutional level. In 2005, the boards of NTNU and SINTEF defined a long-term common strategy around several areas, including internationalisation; research and industrial policy; research equipment and infrastructure; and academic priorities.

3.4 Other public research-performing organisations

Besides the University and CRPs, Luxembourg is home to several other smaller public research organisations, including the following:

Virtual Resource Centre for Knowledge about Europe (CVCE)

CVCE is a public research centre created in 2002 and financed by the Ministry of Higher Education and Research. It focuses on European integration history and politics and employs approximately 40 people. The Centre's budget has grown considerably since 2002 and amounted to nearly EUR 4 million in 2014, much of it in the form of a block grant governed by multiannual performance contracts signed with the Ministry of Higher Education and Research. Like the CRPs, CVCE secures additional funding from national and European research programmes and contract research.

Max Planck Institute (MPI) Luxembourg for International, European and Regulatory Procedural Law

MPI was founded in 2013. It is one of very few Max Planck Institutes located outside of Germany. Luxembourg finances the Institute entirely – at a cost of around EUR 12 million a year – as part of its broader strategy to develop centres for academic excellence and higher education. The MPI focuses on European law – one of the priorities of the University of Luxembourg. Both institutions expect to co-operate in the area. The MPI also plans to co-operate with international legal institutions, such as the Luxembourg-based European Court of Justice.

The Institute hosts three departments: the Department of Public International Law, the Department of European and Comparative Procedural Law, and the Department of Regulatory Procedural Law. It currently has 65 employees; an increase to 150 employees is under discussion.

Central Service for Statistics and Economic Studies (STATEC)

STATEC is an independent body under the supervision of the Ministry of the Economy. Its main mission is to collect and provide statistics to the general public. The new STATEC law of 2011 allows it to conduct independent research around the following areas: economics, demographics, and societal and environmental modelling.

Centre Hospitalier du Luxembourg (CHL)

CHL is a public organisation under the authority of the Ministry of Health. It was established in 1976 and is currently equipped with 579 beds. Much of the medical research at CHL is done in collaboration with LIH. CHL publishes an average of 100 research papers a year.

National Health Laboratory (LNS)

LNS was established in 1980. The laboratory – which was until 2012 part of the Ministry of Health – became a public-law institution in 2013. It undertakes multidisciplinary research focusing on human medicine, epidemiology and hygiene; it is also responsible for drug and food control, and toxicological analysis. LNS employs approximately 200 people.

Luxembourg Natural History Museum (MNHN)

MNHN hosts the national scientific research centre on natural heritage, created in 1982. The research centre collects data and performs analysis.

European Centre for Geodynamics and Seismology (ECGS)

ECGS was created in 1988 through the European Commission's Open Partial Agreement on prevention, protection and assistance against technological and major natural risks. ECGS undertakes research around tectonic distortions, earthquakes and space techniques. It runs an underground geodynamics laboratory in Walferdange with the necessary scientific and technical equipment for the study of deformation in tectonically active zones.

Robert Schuman Centre for European Studies and Research (CERE)

CERE was established in 1990. It currently employs six people and undertakes research on the history of European integration, as well as Luxembourg's positioning within this process.

Note

1. All reports are online at the Ministry of Higher Education and Research website, www.mesr.public.lu/recherche/rapports_evaluation/index.html (accessed 11 April 2014).

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Chapter 4.

The role of government in Luxembourg

This chapter examines public activities that have a bearing on the Luxembourg innovation system. It begins with an overview of the historical evolution of science, technology and innovation policy in Luxembourg. It then examines the main policy actors and governance arrangements. Finally, it reviews current policies in the light of observations made in earlier chapters and outlines areas in need of dedicated policy attention.

4.1. The evolution of science, technology and innovation (STI) policy in Luxembourg

Luxembourg's (STI) policy is relatively recent. The underlying cause for the rather late adoption of explicit STI policies is that the country long lacked the key components that define a mature innovation system, such as a university, public research institutes, specialised government agencies and dedicated government programmes that support both public and private research and innovation. All these elements had to be created more or less from the start during the last three decades. From the 1980s onwards, Luxembourg's innovation system and policy have undergone remarkable development and change. Luxembourg has built a wide range of specialised institutions and put in place the legal and regulatory frameworks required by a mature innovation system.

Innovation policy and the emergence of a mature innovation system

One of the earliest institutional innovations was the establishment of Luxinnovation. Created in 1984 as an agency supporting innovation – particularly by small and medium-sized enterprises (SMEs) – through a range of services, Luxinnovation was a milestone in the development of the institutional landscape underpinning the country's innovation policy. It was also a first clear sign of growing awareness of the role of innovation and SMEs, as became more salient later on.

Major steps to build an advanced innovation system followed in the late 1980s. The creation of Luxembourg's public research centres (CRPs) was based on a framework law on public-sector research passed in 1987. It was certainly the most important new development of the time, leading to the establishment in 1987 of CRP Gabriel Lippmann and CRP Henri Tudor – which covered mainstream technological fields such as information and communication technologies, and materials, energy and environment – and CRP Santé in 1988. Following the establishment of the CRPs, the socio-economic research institution CEPS/INSTEAD became a public establishment in 1989.

In a number of respects, however, the emergent system was still only partially developed. Among other things, it lacked a modern institutional framework for governance, as well as funding of research and innovation. The establishment in 1999 of the Ministry of Higher Education and Research and a new research-funding agency, the Fonds national de la recherche (FNR) – whose activity at the time (e.g. before the establishment of the University of Luxembourg) mainly focused on funding the CRPs, as well as the predecessor organisations of the University – were major institutional innovations. Thus, by 2000, Luxembourg had put in place some of the major legal and institutional pillars required for developing a fully-fledged innovation system. Building a sound institutional basis can be seen as a precondition for the government's decision to increase public expenditure for research and development (R&D), from a mere 0.08% to 0.3% of gross domestic product (GDP) over a period of five years. This turned out to be only the beginning of a prolonged period of expansion of the research system. In 2005, the government published the National Plan for Innovation and Full Employment 2005-08, which indicated strong commitment to the Lisbon strategy and the Barcelona target of the time and set a target 1% of GDP increase of public research expenditure by 2010. Expanding public research funding, in turn, facilitated new initiatives in the first half of the 2000s and spurred the newly created FNR to start a number of programmes. The first four FNR programmes (SECOM, NANO, EAU and BIOSAN) established in 2000 were followed by VIVRE in 2002, and TRASU and SECAL in 2004.

In the early 2000s, however, Luxembourg was still missing one major element of a modern research and innovation system – a national university– since it traditionally sent its students to study at higher education institutions abroad. While the mobility implicit in this arrangement had some obvious merits, establishing a university that could play a key role in high-quality research and education seemed vital to fostering an advanced research and innovation system. After some public debate (see Chapter 3), the University of Luxembourg was established in 2003, complementing the public research system.

Improving the governance of a rapidly expanding system

The University of Luxembourg expanded in the following years and became the single largest research-performing institution in the country. In parallel, the CRPs also grew significantly. The concomitant expansion – both in terms of scale and complexity – of the rather young research and innovation system predictably engendered new policy challenges. It is during this phase that the government of Luxembourg decided to request a first OECD review of Luxembourg's innovation policy (OECD, 2007). This review had a major impact on innovation policies in the years to come, since the government of Luxembourg opted to take on all of its major policy recommendations. Partly overlapping with the review, the FNR carried out a foresight study in 2006-07, which was to have an impact in terms of the research priorities set at a national level.

The OECD review paved the way for an important improvement in the governance of Luxembourg's young and growing public research system, thanks to the creation of performance contracts between the government and the CRPs, CEPS/INSTEAD, the University of Luxembourg and the relevant government agencies (FNR and Luxinnovation). The performance contracts (now in their third round) provided a framework for governance in the public research sector and helped clarify the roles of the various research-performing institutions and agencies. They also enabled a shift to global budgets and multiannual planning, by defining research priorities, goals and indicators, as well as evaluation and reporting schemes. The consensus among innovation performers and agencies is that the contracts are a useful instrument to structure and enhance governance while retaining operational autonomy. The performance contracts, and their subsequent evaluations, helped these organisations strengthen their strategy formulation and management capabilities.

The government also made an attempt to improve horizontal co-ordination by creating a Superior Committee for Research and Innovation in 2008), entrusted with supporting the development of national research and innovation policies and advising the government on their implementation. The Committee is co-chaired by the Minister of Higher Education and Research and the Minister of the Economy and Foreign Trade; its other members are scientists, business people and representatives from civil society. Its impact seems to have been limited.

The funding landscape for research has changed significantly since the first OECD review. The FNR has been entrusted with allocating much project and programme-based funding of CRPs and the University, with some notable exceptions – e.g. the significant funding channelled through the Health Sciences and Technologies Action Plan (the "biomedical initiative"). The FNR has also extended its programme portfolio: to foster the local science base and promote internationalisation, it operates (among others) the ATTRACT and PEARL programmes to attract excellent researchers, as well as the INTER Mobility Programme promoting participation in international research projects. The FNR has also started providing targeted support to public-private partnerships

(P/PPs), e.g. via the CORE programme. Luxinnovation, for its part, supports firms participating in European projects through Fit4Europe. The Ministry of the Economy supports cluster initiatives (introduced successively since 2002). Promoted by Luxinnovation, the clusters create networks of public and private stakeholders in fields such as space, materials, information communication technologies (ICTs), eco-innovation and biohealth.

Recent landmark initiatives

The Cité des Sciences, de la recherche et de l'innovation (City of Sciences, Research and Innovation) is a large-scale infrastructure development on the former industrial site of Belval and an important milestone in continuing efforts to consolidate and upgrade the public research system. its purpose is to bring together most of Luxembourg's public research organisations (including the University, most of which is expected to move over 2015-16) and public research centres in one place. Newly built facilities will also house private firms involved in research and support P/PPs, e.g. the Technoport and House of BioHealth. The joint location of activities for all these organisations in the Cité des Sciences is expected to create synergies.

The Health Sciences and Technologies Action Plan (commonly referred to as the "biomedical initiative") was announced in mid-2008 with the goal of establishing biomedicine as a key innovation driver for Luxembourg's economic diversification. The action plan originated in the Ministry of the Economy, but is a joint initiative with the Ministry of Higher Education and Research and Ministry of Health.

The University's two interdisciplinary centres – the Luxembourg Centre for Systems Biology (LCSB) and the Interdisciplinary Centre for Security, Reliability and Trust (SnT) – were established in 2009. They have expanded rapidly and are increasingly visible at the international level.

Consolidation

A new CRP law enacted in 2014 confirms the status of CRPs as autonomous public legal entities, clarifies the terms of their relationship with the Ministry of Higher Education and Research, and updates their missions to promote knowledge and technology transfer, training and lifelong-learning, and scientific co-operation at national and international levels; it also introduces more transparent and open recruiting procedures.

In 2015, CRP Gabriel Lippmann and CRP Henri Tudor have merged to become the Luxembourg Institute of Science and Technology (LIST), and CRP Santé has been renamed the Luxembourg Institute of Health (LIH) and incorporates the Integrated BioBank of Luxembourg (IBBL). The Luxembourg Institute of Socio-Economic Research (LISER) (formerly CEPS/INSTEAD) performs both basic and applied research in areas such as population and employment, geography and development, and business and industrial organisation, with the aim of informing social policy making in Luxembourg. The issue of how best to develop the CRPs in relation to each other and the University of Luxembourg, including its two interdisciplinary centres, remains on the agenda. Recent attempts to improve strategic co-ordination among the research performers may contribute to this goal.

4.2 Main policy actors

As in other OECD countries, Luxembourg has a range of ministries and agencies working on innovation policy.

Government ministries

The main policy-making actors are the Ministry of Higher Education and Research, primarily responsible for public-sector research policy, including related to the University and the CRPs; and the Ministry of the Economy, mainly responsible for private-sector innovation policy.

Until 2014, the Ministry of Higher Education and Research was made up of two departments: the Department of Research and Innovation and the Department of Higher Education. The Department of Research and Innovation was responsible for public research policy, policy on human STI resources, valorisation of public research and European programmes; it was also responsible for the FNR, the CRPs and the IBBL. The Department of Higher Education was responsible of higher education policy and institutions, including the University of Luxembourg, the Max Planck Institute Luxembourg and the Institut universitaire international. The two departments merged in late 2014 to strengthen the linkages between higher education, research and innovation, as well as provide a common strategic orientation to the University and CRPs. Nevertheless, the Ministry of Higher Education and Research remains very small in terms of its workforce, particularly in light of the expansion and growing complexity of the research system over the last decade.

The Ministry of the Economy is made up of seven general directorates. The General Directorate of Research, Intellectual Property and New Technologies is the most involved in innovation matters; it includes the Directorate of Research and Innovation (responsible for national and international innovation policies affecting business enterprises); the Intellectual Policy Office; and the Directorate of New Technologies (responsible for implementing action plans for health and eco-technologies). The Ministry of the Economy funds business innovation, using the policy instruments defined in the 2009 R&D and Innovation Law.

Other sectoral ministries – including the Ministry of Health; the Ministry of the Environment; the Ministry of Agriculture, Viticulture and Rural Development; and the Ministry of State, Media and Communication Service – are involved more peripherally and active only in areas of interest to their mandates. The Ministry of Finance is omnipresent in budgeting issues.

Fonds national de la recherche (FNR)

The FNR is one of the main funders of research in Luxembourg. It was created by the law of 31 May 1999 with the intention of giving a supplementary impulse to the country's public-sector research activities. Today, the FNR sees itself as a driving force for Luxembourg's innovation capabilities, focusing on three strategic objectives to foster research with impact:

- *Attaining scientific leadership in key areas*. The FNR seeks to help establish international research excellence in Luxembourg by setting high quality standards and attracting and training the most talented scientists. The FNR aims to build

critical mass in key research areas, with a view to supporting economic development and societal progress.

- *Turning public research into a competitive advantage for Luxembourg*. The FNR aims to support Luxembourg's economy by supporting industry-informed research, reinforcing co-operation between public research and innovative industries, and facilitating the commercial exploitation of research results.
- *Anchoring science and research in society*. The FNR aims to promote active exchange between scientists and the public to embed research in the public consciousness as an important pillar of Luxembourg's knowledge society.

The FNR invests public funds in research projects in various branches of science and the humanities, with an emphasis on selected strategic areas. The FNR has a strong focus on excellence in scientific research: all FNR funded research projects are selected exclusively through an independent peer review process. Beyond its traditional role of funding agency, the FNR's portfolio of instruments include programmes to support training of researchers at PhD and postdoctoral levels, to attract excellent researchers from abroad, to foster international collaborations, and to promote collaborations with the private sector and the industrial exploitation of research results. Moreover, the FNR has programmes promoting scientific culture and interest in research in Luxembourg, especially among young people. The various instruments are discussed in some detail in the relevant parts of the chapter that follow.

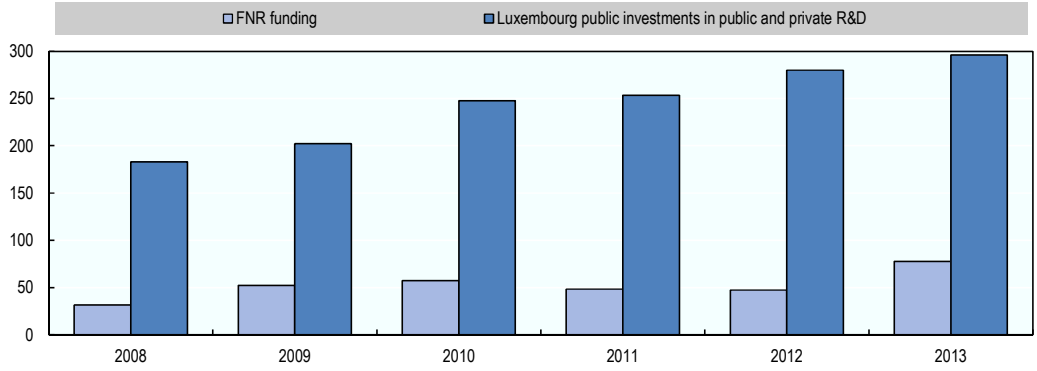
The FNR is a public establishment with scientific, financial and administrative autonomy. Like the University and CRPs, it has a four-year performance contract with the Ministry of Higher Education and Research. The contract defines the budgetary framework and specifies the overall strategy of the FNR. The Secretary General of the FNR is the chief executive of the organisation, appointed by the FNR Board subject to approval from the government. The Secretary General heads the agency – which numbers 26 employees – and manages its day-to-day operations. The FNR Board supervises the activities and sets the strategic priorities of the FNR. It is appointed by the government and comprises nine independent directors active in industry, business and civil society. A Ministry of Higher Education and Research official represents the government and provides bilateral advice and information, but has no voting rights. The FNR Board meets at least three times a year. The Scientific Council of the FNR, composed of international scientific experts appointed by the government, acts as an advisory body.

The 2007 OECD review and the latest available evaluation of the FNR (Ministry of Higher Education and Research, 2010) highlighted the positive results achieved by the FNR in promoting research excellence in Luxembourg. The 2010 evaluation also noted some weaknesses, e.g. regarding the valorisation of public research and promotion of a scientific culture in Luxembourg. The 1999 law establishing the FNR was updated in 2014 and has implemented some of the recommendations featured in the 2010 FNR evaluation. For example, it gives more emphasis to valorising research results and disqualifies beneficiaries of FNR funding from sitting on its Board and Scientific Council. It also modifies the governance structure of the FNR to strengthen its autonomy and broadens the types of organisations eligible to receive FNR funding to include non-profit research organisations.

The level of funding allocated by the FNR has increased sharply in recent years, reaching EUR 78 million in 2013 (Figure 4.1). Nevertheless, FNR funding only accounts for about one-fifth of total public investments in public and private R&D in Luxembourg. Ongoing debate is taking place as to whether the share of FNR funding should increase,

which would entail a decrease in the share of funding to the CRPs and University channelled through block grants. Subsequent sections of this chapter discuss the debate.

Figure 4.1. **Total Luxembourg public investments in public and private R&D and the FNR component, million EUR (MEUR)**



Source: FNR (2014), *Annual Report 2013*.

To facilitate international joint funding, the FNR has signed a number of agreements with funding agencies in other countries (see Section 4.7 on internationalisation). It also actively participates in several international networks, including EUROHORCs (European Heads of Research Councils) and Science Europe (an association of European research-funding organisations and research-performing organisations).

Luxinnovation

Luxinnovation is Luxembourg's national agency for business development and innovation, established in 1984. Since 1998, it is funded jointly by the Ministry of the Economy, the Ministry of Higher Education and Research, the Chamber of Commerce, the Chamber of Crafts and FEDIL (the Luxembourg business federation). Luxinnovation currently employs 45 people. It derives the bulk of its budget from the government, primarily the Ministry of the Economy. Its budget has increased over time, reaching EUR 4.2 million in 2013 (compared to EUR 2.6 million in 2008).

Luxinnovation has no direct funding role: its main mission is to offer tailor-made advice and technical assistance to private firms, start-ups and, to a lesser extent, the University and CRPs. Its services are free of cost. Its activities are defined in multiannual performance contracts signed with its shareholders. According to the 2014-17 performance contract, Luxinnovation has five main objectives:

- *Support and promote participation in national and international R&D and innovation programmes*. Luxinnovation provides information on R&D and innovation programmes sponsored by the government, helps develop applications, finds suitable partners and provides advice on intellectual property rights. Luxinnovation is the national contact point for European programmes and represents Luxembourg in several R&D and innovation programmes and agencies, including Horizon2020, the European Space Agency, EUREKA and EUROSTARS.
- *Manage the Luxembourg Cluster Initiative.* Luxinnovation is responsible for organising events and managing projects in the clusters within the framework of the initiative.

- *Support start-ups.* Luxinnovation promotes the creation of innovative firms in Luxembourg. The agency supports and provides guidance to entrepreneurs during the administrative steps of creating a firm. It looks for suitable partners as well as possible financing opportunities.
- *Support SMEs and crafts.* Luxinnovation manages government programmes promoting innovation in SMEs and young innovative firms.
- *Promote innovation and research.* Luxinnovation informs and promotes innovation and research initiatives among all types of actors, by providing general information on innovation programmes, intellectual property (IP) and European programmes; organising thematic events; and publishing brochures and managing the national innovation web portal on innovation and research.

Performance contracts include indicators to assess Luxinnovation's performance. Most indicators capture the number of project applications or of companies that benefitted from Luxinnovation's services; others measure the number of start-ups created or the number of patent applications. These indicators, however, do not necessarily reflect an increasing level of innovation activity in Luxembourg firms; moreover, they may be strongly correlated to the economic cycle – especially with regard to the number of start-ups or patents. The most recent available evaluation of Luxinnovation highlights the need to use indicators that reflect Luxinnovation's overall impact, rather than the outputs it generates.

As already highlighted in the 2007 OECD Review, Luxinnovation plays an important role in ensuring greater participation of small firms in innovation-related programmes and activities. Business-sector organisations are generally very appreciative of the service offered by Luxinnovation. The 2010 evaluation of Luxinnovation, however, revealed some areas for improvement. Like the 2007 OECD review, it recommended streamlining and prioritising Luxinnovation's activities, e.g. by targeting specified priority sectors. This would also mean dedicating more time and support to specific types of clients (e.g. young innovative companies, growth companies and particular research groups) to help them develop their project from idea to market while ensuring a stronger impact on Luxembourg's economic development and international attractiveness. The focus of activities described in the 2014-17 performance contracts, however, remains very broad and without sectoral prioritisation.

Another issue that emerged in the 2010 evaluation concerns insufficient levels of collaboration between Luxinnovation on the one hand and the University and the CRPs on the other. The University and CRPs considered the services offered by Luxinnovation in the context of European programmes as too generalist to provide real value-added. The level of participation of public research actors in European programmes has improved since the time of the evaluation, but still remains weak. Efforts to improve participation rates could benefit from stronger co-operation between Luxinnovation, FNR, the CRPs and the University. The government should explore options to give the FNR a formal role in providing assistance to research-intensive actors, including both public and private organisations, in European programmes.

4.3 Governance: Steering, co-ordination and evaluation

The 2007 OECD Review paid much attention to governance of the still-nascent Luxembourg innovation system and made several recommendations on improving strategic steering and co-ordination (Box 4.1). The government implemented most of the Review's recommendations, though with sometimes mixed results, as discussed below.

Box 4.1. Recommendations from the 2007 OECD Review on improving governance

Clarify the role of actors. To build an effective innovation system, the role of the actors in Luxembourg's research and innovation system needs to be adapted to the tasks. It will therefore be necessary to separate more clearly the functions of policy formulation and implementation and to periodically assess the role of actors involved in the governance of innovation policy.

Improve co-ordination. To ensure efficient use of increased public investment in research and innovation, the government will need to improve co-ordination among policy actors, including the major ministries in charge of R&D policies (the Ministry of Higher Education and Research and the Ministry of the Economy), and aim at better horizontal co-ordination of sectoral policies.

Improve strategy formulation and management capabilities. Increased public investment and the growing sophistication of Luxembourg's innovation system require reinforcing the capacity to formulate strategies and manage their implementation. This applies in particular to the ministries in charge, whose staff should be increased. In addition, more use should be made of external advice in managing the change process.

Establish an Advisory Board on Science and Technology Policy. In view of the tasks to be accomplished to build up Luxembourg's innovation system over the coming years, consider establishing a temporary Advisory Board on Science and Technology Policy to be chaired either by the prime minister or by one or several ministers. Its main task would be to monitor progress towards implementing the government's agenda for strengthening Luxembourg's research base, advising the government, and initiating complementary studies and evaluations. The Board's members should have a strong background in business, science and innovation policy. A sufficient number should be non-residents who can bring experience from outside Luxembourg. In view of limited resources, an existing body, such as the Inter-ministerial Co-ordination Committee for Research and Technological Development, could provide the secretariat for the Advisory Board.

Set science and technology priorities. Building up the research base in Luxembourg requires a number of discretionary investment decisions, meaning that a purely bottom-up approach is insufficient. The ongoing foresight study should be used to derive priorities for such decisions. In the meantime, consultations with end-users of research could provide useful information for sharpening research priorities in the university and CRPs.

Steer public research institutions. Enhancing accountability and, ultimately, efficiency requires a clear mission statement for each public research institution (PRI) and agency; these mission statements should be derived from strategic audits of the respective institutions. The current contractual arrangements between the government and PRI (e.g. the multiannual programmes of CRPs) should be replaced by state-of-the-art performance contracts.

Source: OECD (2007), *OECD Reviews of Innovation Policy: Luxembourg 2007*, http://dx.doi.org/10.1787/9789264010284-en.

Strategy formulation and national priorities

Given Luxembourg's small size, the 2007 OECD Review highlighted the need for government to set some top-down priorities. To attain the right balance between top-down and bottom-up initiatives, the Review recommended a participatory strategy approach designed to build a shared vision of the desired collective achievements among all private and public actors. Such a national strategy process has yet to be carried out, though several lists of priorities have been independently identified by government ministries and agencies, as well as research-performing organisations. For instance, the

Ministry of the Economy has several sectoral actions plans, as well as an ongoing cluster initiative, prioritising certain sectors and technologies as part of its economic diversification strategy (see Section 4.4); the FNR has a limited set of broad thematic research priorities implemented through its main competitive funding programme, CORE (see Section 4.5); and the University of Luxembourg and CRPs all have their own organisational research priorities largely reflecting research areas where they have acquired some critical mass over the years (see Chapter 3). Furthermore, the growing role of EC funding introduces another set of research and innovation priorities, derived from Horizon2020, which could play a more prominent role in the future (see Section 4.7). There is considerable overlap between all of these priorities, but also some misalignment, particularly between those set by the government (e.g. the FNR and the Ministry of the Economy) on the one hand and those set by the research-performing organisations on the other.

Overall, Luxembourg would benefit from regularly revisiting the necessity, formulation and implementation of national priorities. Most advanced OECD countries prepare dedicated national STI strategies on a five to ten-year cycle (see Box 4.2). These serve several functions in government policy making. First, they articulate the government's vision regarding the contribution of STI to the country's social and economic development; many governments have viewed innovation policies as an important tool both for strengthening growth and addressing a range of global and social challenges, including climate change and health. Second, they set priorities for public investment in STI and identify the focus of government reforms; they also mobilise STI actors around specific goals and may help steer investments by private actors – and increasingly by autonomous universities and PRIs – towards priority areas or technologies. Third, elaborating these strategies allows governments to engage stakeholders (i.e. the research community, funding agencies, business, civil society, and regional and local governments) in broad consultations, thereby helping to build a common vision of the future and facilitating co-ordination within the innovation system (OECD, 2014).

In 2014 the government drafted the *Luxembourg Strategy for Smart Specialisation* and continues to submit annual National Reform Programme plans to the European Commission as part of the so-called "European Semester", but neither of these qualifies as a national STI strategy. Luxembourg would benefit from a full-fledged national STI strategy articulating the links between research investments and their likely impacts on the government's economic diversification, social well-being and sustainability goals. To be effective, the strategy process should be inclusive, reflective, forward-looking and comparative – though it should also take place relatively quickly, ideally within a six-month period. It should be jointly co-ordinated by the Ministry of Higher Education and Research and the Ministry of the Economy – though staff shortages and capability gaps in both ministries may need to be addressed before they can assume such a role. The strategy should pay particular attention to implementation and introduce the necessary funding and regulatory reforms to enact its objectives. All of the main actors of the innovation system – including government ministries, agencies and other intermediaries, and research performers – should also be asked to formulate and implement strategic organisational plans reflecting the orientation and objectives set forth by the national strategy.

Box 4.2. Examples of recently developed national innovation strategies in small innovation-intensive OECD countries

Country responses to the *OECD Science, Technology and Industry Outlook 2014* (OECD, 2014) policy questionnaire have revealed both similarities and differences in goals and policy priorities across countries; they also point to some international features in national STI strategies, as well as some broad cross-country policy patterns. A first similarity is that almost all countries have given high priority to business innovation and innovative entrepreneurship, whatever the approach and modalities of public action. Second, most countries aim to consolidate the innovation ecosystem by strengthening public R&D capacity and infrastructures, improving overall human resources, skills and capacity building, and improving framework conditions for innovation (including competitiveness). Small open OECD countries with high exposure to trade and foreign direct investment are also more likely to consider the challenges raised by STI globalisation and increasing international co-operation as major policy priorities.

Below are some examples of national strategies recently developed in small innovation-intensive OECD countries.

Denmark

The Danish innovation strategy, "Denmark, land of solutions", was published in 2012. The Ministry of Science, Innovation and Higher Education was responsible for developing the strategy and the Ministry of Business and Growth was also involved in the process. The strategy contains 27 policy initiatives on research, innovation and education. It focuses on promoting knowledge exchange between companies and knowledge institutions, between the public and the private sector, and within and beyond national borders. Economic growth, job creation and solutions to social challenges were also focus areas. Denmark carried out a national dialogue with non-governmental stakeholders to prepare the strategy.

Netherlands

The Dutch research strategy, "2025 Vision for Science, choices for the future", was released in 2014 by the Ministry of Education, Culture and Science. The strategy acknowledges the important contribution of Dutch science to the national economy and focuses on achieving the broadest possible impact for scientific results by promoting co-operation between research organisations and the business sector; promoting open and participatory science; highlighting the important role of applied science universities in the innovation ecosystem; and acknowledging the key role of higher education institutions in skill development. The strategy also emphasises the importance of valorising research results and the need to attract more women to scientific careers.

Sweden

Sweden's 2012 National Innovation Strategy focuses on six topics: i) highly skilled people with innovative ideas; ii) research and higher education for innovation; iii) framework conditions and infrastructure for innovation; iv) innovative firms and organisations; v) innovation in the public sector; and vi) innovative regions and ecosystems. As part of the strategy, the government has increased investments in research and innovation by approximately 15% over 2012-16. The additional investments target research infrastructure, as well as basic and industrial research. The Strategy also identifies priority areas in the life sciences, mining and steel, wood, forest raw materials and biomass, and sustainable community development.

Box 4.2. **Examples of recently developed national innovation strategies in small innovation-intensive OECD countries** (*continued*)

Switzerland

One of the objectives of the Swiss Federal Council's current Legislative Plan targets the education, research and innovation (ERI) sector. With the agreement of the Cantons, and based on the strategic plans of grant recipients, the Federal Council has established three ERI "policy guidelines" for 2013-16, with their corresponding objectives. One of the policy guidelines directly addresses research and innovation. The corresponding objectives are to position Switzerland's international reputation as a competitive location for research and economic activities, by increasing the amount of grant funding awarded on a competitive basis for research and innovation; to ensure that Switzerland holds a top position in promising fields, through targeted measures to improve research, development and innovation capabilities, while leaving enough room for unconventional research approaches; to invest in strategically important research infrastructures at the national and international levels; to maintain the strategic importance of international co-operation and networking with European and non-European countries; and to improve co-operation between PRIs and the private sector.

Source: Country responses to the *OECD Science, Technology and Industry Outlook 2014* (OECD, 2014) questionnaire survey.

Performance contracts and evaluation arrangements

A key recommendation of the 2007 OECD Review was to replace existing contractual arrangements between the government and the country's public innovation actors – whose management was burdensome for the Ministry of Higher Education and Research – by state-of-the-art multiannual performance contracts. These have the advantage of providing a framework for clearly defining multiple goals to be pursued autonomously by public innovation actors. Luxembourg followed up on the OECD recommendation by instituting a comprehensive system of performance contracts in 2007-08. Such contracts have been concluded between the Ministry of Higher Education and Research (and other principals) on the one hand and the University of Luxembourg, the CRPs, the FNR and Luxinnovation on the other hand. The Performance contracts state the organisation's main objectives and thematic orientations for the next three years (four years in the latest contracts) and include the budget trajectory for the relevant period. In the case of the CRPs and University, the budget constitutes the so-called "block funding" they will receive from the Ministry of Higher Education and Research. The Performance contracts also contain a future performance agreement, which includes a number of selected and formulated performance indicators that are monitored during the period of the contract. Failure to meet indicator-based targets can lead – and has in fact led – to block-funding cuts, negotiated through amendments (known as "*avenants*").

Organisations are currently into the third cycle of four-year performance contracts, following two three-year cycles (though the University's cycle was always four years). Performance contracts have evolved between cycles, though there is now considerable stability, e.g. in the chosen performance indicators. Overall, the system is well designed and the targets and indicators are realistic. Performance contracts provide a framework for forward-looking negotiations that are well adapted to the country's small size. At the same time, Luxembourg has avoided the "small-system trap", characterised by a tendency towards micro-management and the use of too many indicators and steering instruments.

There may still be room for improvement. First, performance contracts should be more strongly coupled to evaluations of public innovation actors. The Ministry of Higher Education and Research should examine the 2014-17 performance contract of the FNR, which presents a systematic approach to coupling strategic objectives, criteria, measurement methods and indicators to support its own exercises and studies: such an approach could become a standard for other organisations' performance contracts.

Second, performance contracts should be used to embed more deeply horizontal collaboration between research-performing actors. Organisation-specific performance indicators can sometimes limit the scope for horizontal collaboration, with research performers focusing solely on meeting the performance targets assigned to them. The current cycle of performance contracts tries to overcome this tendency, by requiring a common strategic plan for all research organisations that features a ten-year perspective for co-operation among the CRPs and the University. This ambitious approach has yet to be put into practice, but points in the right direction.

Third, the international dimension of performance contracts should be strengthened. In the past, national benchmarks were mostly used to negotiate performance contracts and measure performance. However, being the best in Luxembourg (or the Grande Région) is not enough. Future performance contracts should feature more incentives and internationally oriented indicators, e.g. related to winning international grants and contracts (such as Horizon2020 grants and related programmes), international attractiveness and measuring international reputation. The number and weight of nationally oriented indicators should be reduced correspondingly.

Finally, the Ministry of Higher Education and Research should consider designing a mechanism to reward "overachievement", e.g. winning top international grants or contracts. Organisations do not currently receive extra financial rewards for performing better than foreseen in their performance contracts, but do rightly face cuts in case of underachievement. The position of the Ministry of Higher Education and Research on this issue is that performance contracts establish a minimum level of performance expected of actors; overachievement should therefore not be unusual. Still, if a performance level is significantly surpassed, there should be some reward.

While the government uses performance contracts as a framework for forward-looking negotiations on organisations' future performance, it uses evaluations to assess past and current performance. All of the main research and innovation actors are subject to evaluations. Evaluation of the University of Luxembourg focuses on the institutional level and occurs every four years according to an agreed set of guidelines; the University was evaluated in 2009 and 2013. Evaluations of the CRPs are performed at the level of the research units, of which several were evaluated over 2010-12. Both the FNR and Luxinnovation were evaluated in 2010; the FNR also commissions evaluations of its programmes, e.g. the *Aides à la formation recherche* (AFR) scheme was evaluated in 2010, and CORE will be evaluated in 2015. On the other hand, none of the Ministry of the Economy's business innovation-support programmes seem to have been evaluated. Overall, evaluation results appear to be used in future decision-making. For example, the findings of the 2010 FNR evaluation informed the new FNR law in 2014, while the evaluation of its AFR scheme led to several important modifications. The next cycle of institutional evaluations is due in 2016-17.

Horizontal co-ordination across government

The task of ensuring efficient use of increased public investment in research and innovation, and managing and addressing the varied needs of an expanded, more

differentiated and interlinked innovation system, entails horizontal co-ordination of the main actors across government. This especially applies to the major ministries in charge of R&D and innovation policies, e.g. for Luxembourg, the Ministry of Higher Education and Research and the Ministry of the Economy. The Ministry of Health plays an important role in ensuring the success of research and innovation initiatives in its area of competence (e.g. the biomedical area). Other ministries also play an important role in Luxembourg's effort to strengthen innovation, and need to be included in attempts to better co-ordinate related policies.

Like many other countries, Luxembourg has tried to formalise co-operation between key ministries in charge of R&D and innovation, e.g. through the Inter-ministerial Co-ordination Committee aiming to co-ordinate the innovation policy and related activities of the Ministry of Higher Education and Research and Ministry of the Economy. However, the Inter-ministerial Committee is no longer active; it may have lost some of its purpose following the creation of the performance contracts with the innovation agencies and public research performers, which have set the stage for a clearer assignment of tasks and more structured decision processes. The two ministries do hold regular informal consultations, and co-operation seems to work well on a daily basis. There may, however, be some need for structured consultation on a more long-term strategic agenda.

Over the past two decades, a wide range of countries have established high-level advisory committees – or councils, as they are often called. Their role, among others, is to expound on key issues and bottlenecks to be addressed by innovation policy and to act as a platform for discussing and advancing strategic agendas for developing the innovation system. Following the first review of Luxembourg's innovation policy, the Superior Committee for Research and Innovation, co-chaired by the Minister of Higher Education and Research and the Minister of the Economy, was created in 2008. The Superior Committee's members comprise scientists, business people and representatives of civil society, typically with international experience. The Committee was entrusted with helping to formulate and develop a coherent and effective national research and innovation policy, and advising the government on its implementation. Its impact on policy development, however, appears to have been limited, and its role has been rather unclear in practice: it did not gain visibility, e.g. by producing reports that would structure the innovation policy discourse. However, given the continued need to achieve and support co-ordinating and advancing a strategic agenda for Luxembourg's innovation system, a high-level advisory committee could fulfil a useful function. If retained, a reconstructed Superior Committee for Research and Innovation should be given a more clearly defined role, closely linked to Luxembourg's strategic policy agenda. In particular, the Committee could be entrusted with monitoring the implementation of a national innovation strategy. This would require adapting its mandate, organisation and *modus operandi*.

A different kind of co-ordination body has emerged under the guise of a committee bringing together the heads of the CRPs, the University and occasionally the FNR. The purpose of this committee is to advise the Ministry of Higher Education and Research on conceiving and implementing research, development and innovation (RDI) policy and related activities. The committee's role is augmented by the fact that the 2014-17 performance contracts oblige the CRPs and the University to come up with a common ten-year strategic co-operation plan. Incentives for inter organisational collaboration between the CRPs and the University could be further strengthened in the next generation of performance contracts, depending on the experience in the current round. The research

organisations' move to the new Belval site should also provide an opportunity for more inter-organisational collaboration. The recent merger of the two departments in charge of higher education and research within the Ministry of Higher Education and Research can be also seen as a major opportunity in this regard; it allows increasing permeability between the research and higher education agendas, which in turn can help improve relationships in the innovation system – including between the CRPs and the University.

4.4 Supporting business R&D and innovation

The Ministry of the Economy leads the government's efforts to promote R&D and innovation activities in the business sector. These efforts focus on the following:

- *Providing firms with R&D funding and other support eligible under state aid rules*, through a range of programmes to support firms' research and innovation activities. This constitutes by far the largest share of government investments in business R&D and innovation.
- *Promoting economic diversification, for example, through sectoral action plans* involving a mix of different policies and instruments covering several sectors. This offers opportunities for Luxembourg to diversify its economy.
- *Promoting networks and clusters*, primarily through the Luxembourg Cluster Initiative, managed by Luxinnovation. There are currently six clusters, covering biohealth, automotive components, eco-innovation, ICTs, materials and space.
- *Supporting incubation infrastructure*, including through government funding of the Technoport and House of BioHealth incubators for start-up and young firms in Luxembourg.
- *Promoting favourable framework conditions for innovation*, including broad macroeconomic conditions, through international openness, ICT and transport infrastructure, the business environment affecting entrepreneurship, the IP regime and availability of venture capital. Chapter 2 already discussed all these conditions extensively; this section is limited to describing support for financing innovation and for IP protection.
- *Supporting the participation of Luxembourg firms in European programmes*, thanks to efforts led by Luxinnovation, which is the National Contact Point for European programmes in Luxembourg. Section 4.7 discusses these programmes extensively.

Luxinnovation plays a prominent role in promoting R&D and innovation activities in the business sector. While it does no direct funding, it manages most of the Ministry of the Economy's business R&D and innovation-support programmes. It also offers a variety of support services to raise awareness of government support programmes, provide businesses coaching and help innovative firms find partners.

Providing firms with R&D funding and other innovation support eligible under state aid rules

Most existing policy instruments to promote innovation in the business sector are defined by a 2009 law concerning the promotion of RDI. The 2009 RDI law updates and replaces a former Law on State Aid for Research, Development and Innovation dating

back to 1993.[1] The programmes defined by the 2009 RDI law cover a broad range of instruments: R&D projects and programmes; instruments focusing explicitly on young firms; and mobility programmes or mechanisms to facilitate protection of IP. The programme budgets are allocated by the Ministry of the Economy following guidelines contained in the 2009 RDI law, which defines the maximum shares of public co-funding that companies are eligible to receive for each individual project (Table 4.1). Except for programmes promoting fundamental research activities in firms (for which state aid covers 100% of eligible costs), the maximum share of government co-funding varies between 25% and 75% – allocated progressively in favour of small firms.[2] It should be emphasised that co-funding distributed through these programmes is allocated on an eligibility basis: the Ministry of the Economy makes no attempt to prioritise or select along sectoral or thematic lines, and funding is available to all firms that meet the state aid eligibility criteria. Moreover, funding is allocated to eligible firms without peer-review evaluations to assess project applications' scientific quality.

Table 4.1. **An overview of the 2009 RDI law – funding instruments and eligible share of state aid (%)**

Programme	Type of R&D programme or project supported	Size of enterprise or private research organisation		
		Large	Medium	Small
R&D programme or project	Experimental development	25%	35%	45%
	Experimental development + co-operation[1]	40%	50%	60%
	Industrial research	50%	60%	70%
	Industrial research + co-operation[1]	65%	75%	80%
	Fundamental research	100%	100%	100%
Technical feasibility study	For experimental development	40%	50%	50%
	For industrial research	65%	75%	75%
Protection of technical industrial property	Following an experimental development	x[2]	25%	25%
	Following an experimental development + co-operation[1]	x[2]	40%	40%
	Following industrial research	x[2]	50%	50%
	Following industrial research + co-operation[1]	x[2]	65%	65%
	Following fundamental research	x[2]	100%	100%
Aid for young innovative enterprise		x	x	1 000 000 EUR
Innovation advice and innovation support		x[2]	200 000 EUR max. over 3 years	200 000 EUR max. over 3 years
Mobility programme of highly skilled personnel		x[2]	50%	50%
Process and organisational innovation in the service sector		15%	25%	35%
Cluster initiatives[3]		15%	25%	35%
Management of clusters[3]		50% over 5 years max.	50% over 5 years max.	50% over 5 years max.
De minimis measures		EUR 200 000 over a period of three fiscal years		

Note: x= not applicable.

1. If the co-operation involves collaboration between a private and a public research organisation, extra funds are granted up to a maximum of 15% of the original grant.

2. Eligible for de minimis funding.

3. Public research organisations are eligible for these programmes.

Source: Luxembourg Portal for Innovation and Research (www.innovation.public.lu).

The number of applications rose sharply in 2013. As a consequence, the budget allocated by the Ministry of the Economy to R&D projects, public-private collaborations, process and organisational innovation in services, and support to young innovative enterprises increased markedly (Table 4.2). Other programmes received very limited applications between 2010 and 2013; for example, the mobility scheme was requested only once. Between 2008 and 2013, firms from the materials sector accounted for around half of the allocated state aid; firms from the ICT sector accounted for a further third, while firms from the biohealth sector accounted for just 4%. This pattern reflects more or less the sectoral composition of business R&D and innovation activities in Luxembourg. The percentage of applications submitted by SMEs rose from 18% in 2008 to 32% in 2013 – a positive development.

Table 4.2. **Budgets (MEUR) and number of projects for selected instruments of the 2009 RDI law, 2009-13**

	2009	2010	2011	2012	2013
R&D projects					
Budget allocated by Ministry of the Economy	47.3	33.2	31.7	32.1	75.9
Co-funding from private companies	137.8	87.9	86.4	81.6	201.3
Number of projects	37	38	47	50	83
Public-private collaborative projects					
Budget allocated by Ministry of the Economy	x	0.9	1.4	2.5	8.9
Co-funding from private companies	x	1.7	2.5	5.0	14.5
Number of projects	x	1	3	5	12
Young innovative enterprise					
Budget allocated by Ministry of the Economy	x	4.1	1.9	3.8	6.3
Co-funding from private companies	x	18.4	5.0	9.1	15.3
Number of projects	x	6	3	6	9
Innovation advisory services and innovation-support services					
Budget allocated by Ministry of the Economy	x	0.01	0.12	0.05	0.02
Co-funding from private companies	x	0.02	0.19	0.11	0.04
Number of projects	x	1	7	4	1
Temporary secondment of highly qualified personnel					
Budget allocated by Ministry of the Economy	0	0.05	0	0	0
Co-funding from private companies	0	0.10	0	0	0
Number of projects	0	1	0	0	0
Process and organisational innovation in services					
Budget allocated by Ministry of the Economy	x	0	0.18	0.22	3.1
Co-funding from private companies	x	0	0.59	0.74	10.6
Number of projects	x	0	2	4	11
Protection of technical industrial property					
Budget allocated by Ministry of the Economy	x	0	0.01	0.01	0.06
Co-funding from private companies	x	0	0.04	0.02	0.01
Number of projects	x	0	2	2	5

Note: x = not applicable.

Source: Ministry of the Economy (2015), personal communication.

Some of the main instruments are further described below.

R&D projects: State aid allocated to firms' R&D projects accounts for the bulk of research and innovation support from the Ministry of the Economy, i.e. around 70% of funding in 2013. This amounted to EUR 75.9 million awarded to 83 R&D projects

in 2013 – by far the highest annual expenditure since the introduction of the 2009 RDI law (Table 4.2). Large firms operating in Luxembourg are the main beneficiaries of these funds by volume, but many SMEs also benefit.

Public-private collaborative projects: The 2010 evaluation of Luxinnovation highlighted weak R&D co-operation between the University and CRPs on the one hand, and the business sector on the other. A 2013 assessment by the Haut Comité pour l'industrie (High-Level Committee for Industry)[3] makes a similar observation. The 2009 RDI law includes a specific instrument to promote public-private co-operation: firms engaging in collaborative projects with the University or CRPs are eligible to receive extra co-funding. Initial take-up of the instrument was low, but 12 projects were funded in 2013 with a total allocation of EUR 8.9 million (Table 4.2). This is a promising development.

Young innovative enterprises and other SMEs: A number of instruments specifically target small firms, either by supporting young innovative enterprises or more broadly, SMEs:

- Aid for young innovative enterprises covers the funding needs of start-ups with high growth potential. This programme specifically promotes innovation in young innovative enterprises with less than six years of activity that spent at least 15% of their budget on R&D in the three years prior to participating in the programme. The programme totalled EUR 6.2 million in 2013, funding nine projects (Table 4.1).
- The new "Fit for Innovation" programme targeting SMEs was launched in 2014. As is the case for most business R&D programmes, it is managed by Luxinnovation. SMEs participating in the programme may benefit from external expert advice.
- Both the Ministry of Small and Medium-sized Businesses and Tourism and the Ministry of the Economy offer investment aids to SMEs to a portion of tangible and intangible asset costs.

Process and organisational innovation in services: The 2007 OECD review highlighted the need to develop specific programmes targeting innovation in the service sector. In all OECD countries, public support targeting innovation in services is less developed than public support for typically more R&D-intensive manufacturing companies. Nevertheless, given the importance of the service sector in advanced economies, policy makers are increasingly targeting and promoting service innovation. Yet many knowledge-intensive service companies do not perform R&D in a traditional way: they innovate by changing business processes or developing new combinations, e.g. of legal solutions. Hence, promoting innovation in services may require instruments and programmes tailored to the needs of companies in this sector. The 2009 RDI law created a specific programme offering financing for process and organisational service innovation. After a period of low take-up, 11 projects were allocated EUR 3.1 million in 2013 (Table 4.2).

Promoting economic diversification through sectoral action plans

The Ministry of the Economy, in co-operation with other ministries, is seeking to diversify the economy, based on a multi-specialisation strategy aiming to reduce its dependence on the financial sector. The specialisation strategy targets the following sectors:

- *ICTs*: by creating customised infrastructure in the area of connectivity and data centres, Luxembourg aims to become a location of choice for companies specialising in electronic content distribution and data storage in a highly secure environment. This will be achieved primarily through increasing the number of service providers – e.g. by extending the draft law on electronic archiving, copyright management and IP – and developing companies that use electronic services. In that regard, other sectors are expected to play important roles as ICT users: the logistics sector, through e-commerce; eco-technologies, through smart grids and information technology management; health technologies, with data archiving and management; and space technology (and more generally the industrial and financial sectors), through high-performance cloud computing.
- *Logistics*: the government is seeking to position Luxembourg as an intercontinental and multimodal logistics platform in Europe, primarily in the domain of high value-added logistics.
- *Eco-technologies*: government policy in this area focuses on eco-construction, sustainable mobility and the circular economy. The government is setting up sustainable construction-skill centres to bolster research and innovation and group the players in the area with a view to developing an eco-construction sector.
- *Health technologies*: capitalising on its Health Sciences and Technologies Action Plan (Section 4.3), the government will continue to develop public research in the biohealth area. In addition, the Ministry of the Economy is supporting a new P/PP, the House of BioHealth, an incubator for both start-ups and established firms. This is discussed more fully below.
- *Space sector*: this is an important high-tech sector for Luxembourg, which is home to one of the major players in the sector, the Société européenne des satellites (SES). An entire industry has grown around this major player. Luxembourg became a member of the European Space Agency (ESA) in 2005. The government's space policy primarily aims to contribute to economic diversification; consolidate and enhance existing skills in telecommunications and the media, as well as ground systems; expand expertise in the sector; and give an international dimension to its activities by accessing international networks.

These descriptions highlight the use of a mix of different policies, including regulation and infrastructural investment, to promote selected sectors. Research and innovation policies play varying roles depending on the sector, e.g. a somewhat minimal role in the case of logistics but a more central role in health technologies.

Promoting networks and clusters

Clusters are defined as geographic concentrations of firms, higher education and research organisations, and other public and private entities that facilitate collaboration on complementary economic activities (OECD, 2014). Several studies in the academic literature have shown the importance of proximity and agglomeration for knowledge and innovation spillovers (e.g. Jaffe, Trajtenberg and Henderson, 1993; Rosenthal and Strange, 2005; Agrawal, Kapur and McHale, 2008; Buzard and Carlino, 2009; and Kerr and Kominers, 2010). The main rationale for public policies to promote clusters – for example, through infrastructure, knowledge-based investments, networking activities and training – is to increase knowledge spillovers among actors to make them more innovative and competitive.

The Luxembourg Cluster Initiative was launched in 2002 by the Ministry of the Economy and is co-ordinated by Luxinnovation. Today, it numbers six clusters focused on areas considered key to the sustainable development of the national economy (see Box 4.3). Clusters aim to foster the exchange of knowledge and know-how among members; achieve critical mass and enhance visibility at the national and international level; offer business-development and business-support services to member organisations; promote collaborative R&D projects in Luxembourg and abroad; and facilitate participation in international research and innovation projects, notably through European programmes. Their services include organising networking events, training, education, recruitment and business-development services. The 2007 OECD review welcomed the establishment of the clusters, but highlighted the need to include a larger number of players, including public research organisations and service providers, and to better facilitate cross-sectoral synergies across clusters. Today, most of the clusters include private companies, relevant parts of the University and CRPs, and service providers. Some clusters are also collaborating across sectors, as is the case of the ICT and Space clusters.

Not all clusters have the same characteristics: some, like the Automotive Components or Materials clusters, appear to be primarily driven by the presence of large international firms. Others – like the BioHealth Cluster – appear more closely linked to national research priorities. Together with the Ministry of the Economy, the clusters developed in 2013 a new working framework based on five priority areas: business development; supporting flagship projects; improving brand image for the sector; intensifying promotion; and prospecting and internationalisation. Specific targets were defined for each cluster individually. Most of the clusters' activities seem primarily related to business development and support, rather than to more ambitious strategic research and innovation programmes. This is in spite of connections to relevant teams in the CRPs and the University, as well as to incubators.

Box 4.3. **The Luxembourg Cluster Initiative**

The Luxembourg Cluster Initiative currently focuses on six areas: the BioHealth Cluster, the Automotive Components Cluster, the EcoInnovation Cluster, the ICT Cluster, the Materials Cluster and the Space Cluster.

The establishment of a **BioHealth Cluster** is part of the government action plan to develop strong capabilities in biomedical research and innovation, with a focus on molecular diagnostics and personalised medicine. Cluster members cover a broad range of actors: more than 40 companies or private organisations, approximately 15 service providers – including consulting firms, such as KPMG and PwC, and infrastructure, such as the House of BioHealth – and public research organisations – including LIST and LIH (including IBBL), and the Faculty of Science, Technology and Communication and the LCSB at the University of Luxembourg. The main aim of the cluster is to promote partnerships among members and other companies, both in Luxembourg and abroad. The Cluster secretariat organises visits to international trade fairs, conferences and missions abroad. The Cluster establishes contacts with relevant bio-clusters around the world and is a member of the Council of European BioRegions, a European network of biotechnology professionals. In partnership with Luxinnovation, the Cluster also provides advice and raises awareness of funding opportunities arising from the business-support measures of the Ministry of the Economy, as well as from Horizon2020. The Cluster provides support in getting the necessary information on European programmes; it identifies potential European partners and provides guidance on submitting proposals, as well as assistance with complying with legal obligations.

Box 4.3. **The Luxembourg Cluster Initiative** (*continued*)

The **Automotive Components Cluster** assists its members by organising networking events, themed conferences, and workshops and missions abroad. The Cluster has 11 members – including big players in the automotive component industry (e.g. Goodyear, Delphi and IEE) and service providers (e.g. KPMG or PwC), but no public research organisation. The Cluster defined its future programme and selected five flagship projects in 2014: i) the development of an Automotive Campus, an industrial site specialising in R&D on automotive components offering potential synergies in testing and validation, prototyping, warehousing, training and education; ii) competence mapping and competence creation to develop member skills; iii) the exchange of best practices in manufacturing, product development, purchasing and logistics; iv) services related to training, education and recruitment; and v) business-development services.

The **EcoInnovation Cluster** is active in areas considered strategic by the government, i.e. the circular economy, mobility, sustainable cities and smart technologies. It provides services to more than 100 members, including 90 private firms and public research organisations, such as LIST and the interdisciplinary centre, SnT, at the University of Luxembourg. Cluster members are active in the fields of eco-materials, renewable energies, eco-design and energy efficiency. The Cluster's main aim is to connect different actors (both public and private) to facilitate collaborative projects, as well as R&D and innovation more generally. The Cluster offers assistance in finding business and research partners, identifying funding opportunities for research and innovation in Luxembourg and in Europe, and building P/PPs. The Cluster recently launched the "Organic City – Organic Life in Dudelange" project aiming to transform a former steel-plant industrial site in the city of Dudelange into an eco-district.

The **ICT Cluster** aims to further develop the existing ICT sector in Luxembourg by providing business support and fostering collaborative research and innovation projects. The Cluster numbers more than 100 private companies as members – though some of the big international players with a presence in Luxembourg are notably missing – as well as groups from LIST and the University of Luxembourg. The Cluster mainly covers the following thematic areas: ICT for health and ageing population; e-invoicing and e-payment; and ICT for green and location-based services (in collaboration with the Space Cluster). The Cluster provides assistance and advice on national and European R&D funding opportunities.

The **Materials Cluster** comprises more than 60 companies and public research organisations involved in materials technologies. Some of its members are multinational companies with R&D activities in Luxembourg, such as Goodyear, Delphi, IEE and DuPont de Nemours. Its public research members include the LIST material sciences research unit and the physics and material sciences research unit at the University of Luxembourg. The Cluster has four main objectives: i) to provide its members with value-added services related to their business-development and innovation activities; ii) to extend the Cluster's reach beyond national borders and identify suitable RDI partners; iii) to develop RDI collaborative projects with firms in other sectors; and iv) to define appropriate Cluster governance procedures. The Cluster regularly organises networking events, conferences and workshops. It also provides assistance and support for developing research projects, identifying potential partners and accessing funding schemes both in Luxembourg and at the European level.

The **Space Cluster** focuses on five thematic areas: i) space telecommunications; ii) global navigation satellite system and location-based applications; iii) Earth observation; iv) maritime security and safety; and v) space-related technologies. The Cluster brings together private companies and public research organisations to develop collaborative research projects. Luxembourg hosts many large private players in the space technologies: SES, the world's leading satellite group, was established in Luxembourg in 1985. The Cluster is a platform for business-oriented networking and exchanges. It facilitates the creation of partnerships to develop R&D projects both at the national and international levels, notably through European research and innovation programmes. The Cluster also provides advice and support on national and European funding opportunities.

Source: Luxembourg Cluster Initiative website (www.clusters.lu).

In addition to the government-co-ordinated Luxembourg Cluster Initiative, the Ministry of the Economy offers funding – as part of its state aid programmes – for groups of independent enterprises or research organisations to establish their own cluster initiatives. To be eligible, beneficiaries must be active in a particular sector or region, or must share similar or complementary interests or skills. The state aid can cover two types of expenses: investments in an innovation cluster and management of an innovation cluster. All enterprises and public or private research organisations established in Luxembourg are eligible for these schemes. The recipient of the aid is responsible for managing the installations and activities of the innovation cluster; access to the premises must be open to enterprises and public or private research organisations that wish to use the cluster's installations. The fees for using the installations must reflect the investment, maintenance and management costs. One innovation cluster is currently active, known as Neobuild (Box 4.4).

Box 4.4. **Neobuild: A business-driven "innovation cluster"**

Neobuild was established in 2011 and is supported by the government thanks to the measures introduced in the 2009 RDI law. Neobuild received EUR 2.8 million from the Ministry of the Economy, matched by EUR 4.3 million from private sponsors. The development of Neobuild was driven by private companies active in the field of sustainable construction in Luxembourg. Neobuild focuses on innovation projects around environmental and energy efficiency in buildings, eco-materials, and interactions between ICTs and construction to make buildings and materials increasingly efficient and automated. Neobuild offers support to its members to develop innovation projects around these focus areas, by providing advice and technical analysis and identifying appropriate partners for developing R&D projects. It co-operates with the University and LIST, as well as with the government-co-ordinated Materials and EcoInnovation clusters. It also focuses on technology transfer and member skill development. Neobuild helps its members seek financing to develop innovative products or services. Neobuild actively looks at initiatives and partners outside Luxembourg and aims to connect to all relevant actors active in the field of energy efficiency and construction in the Grande Région. It regularly holds events to connect firms from Luxembourg to suitable partners in Europe.

Source: Neobuild website (www.neobuild.lu).

Supporting incubation infrastructure

The 2007 OECD Review (OECD, 2007) highlighted a handful of incubator initiatives funded by the Ministry of the Economy and CRPs. It called for consolidation of these different initiatives into a single incubator scheme in the interests of improving efficiency and visibility. This has happened to some extent: the former Ministry of the Economy-funded ECOSTART enterprise and innovation centre at Foetz combined with the Technoport Schlassgoart incubator of the CRP Henri Tudor in 2012 to create a single limited company known as Technoport. However, since 2015, a large new actor – the House of BioHealth – has emerged to also offer incubation services.

Reflecting its history, Technoport has two locations, at Foetz and Belval, totalling 12 000 square metres (m^2). Technoport has a staff of five (full-time equivalent) and an annual budget of around EUR 900 000. It has two main shareholders: the Ministry of the Economy and the National Credit and Investment Company, Luxembourg's development

bank. Its overarching mission is to help and support individuals and small teams by validating and bridging their ideas to success. It does this through three platforms:

- *Technology-oriented business incubator*: this is Technoport's core business. The goal is to promote and support the creation and development of innovative and technology-oriented companies in Luxembourg. Technoport provides either individual entrepreneurs or foreign innovative businesses with access to resources – e.g. business-support services and infrastructure – that they typically lack. The incubator hosts on average 25 companies at any given time. As of 2013, 34 firms had grown out of the incubator, 10 of which had been acquired by foreign firms. Most of the firms hosted by Technoport have been created by people with five to ten years of experience in an established firm, who then leave to create their own start-up. The incubator currently hosts very few spin-offs from the University and CRPs.
- *Co-working*: Technoport offers a mix of shared physical space and dedicated events where individuals, small teams and corporations can access multidisciplinary communities of like-minded persons to co-design or co-develop their products or ideas.
- *Fab lab*: this new facility offers users open access to different kinds of equipment (e.g. 3D printers, a laser cutter and milling machines) and services (e.g. 3D modelling and digital fabrication) to materialise almost all types of ideas. It is part of a global network and programme of digital-fabrication laboratories initiated by the Massachusetts Institute of Technology's Centre for Bits and Atoms.

Technoport's visibility has increased with the 2012 merger and its limited company status; it could be further enhanced by the relocation of much of the University and CRPs at Belval. Luxinnovation helps with applications to join Technoport and also jointly organises networking and awareness meetings. While Technoport does not have the same volume of deal flows as similar incubators in other countries, it has good relationships with venture-capital funds and the Luxembourg Business Angel Network, which resulted in hosted companies raising more than EUR 46 million by 2013. Technoport currently has an 85% occupancy rate and will expand in 2015 with a further 3 000 m^2 of available industrial space. However, most domestic demand for space comes from ICT start-ups that have little need for such industrial spaces. The Ministry of the Economy is working with Luxembourg's embassies to attract foreign firms to the incubator. With the Fab lab, the goal is to target a new segment – product designers – that would help Technoport expand its focus beyond ICT start-ups.

A new incubator, the House of Biohealth, was officially inaugurated in early 2015. This P/PP sponsored by the Ministry of the Economy is located close to the Cité des Sciences site in Belval. Despite its name, the incubator is open to firms working outside of the biohealth area; it specifically targets firms working in biotechnology, ICTs and clean technologies in the hope that co-location on a common site will lead to significant synergies and opportunities, such as at the intersection of biomedical research and big data. In this regard, the incubator's scope is somewhat similar to that of the LCSB and IBBL. In fact, the incubator is expected to host both public and private research activities, as well as start-ups and established firms. Ultimately, the House of BioHealth will provide 9 000 m^2 of laboratory space and 6 000 m^2 of office space, which is sufficient to accommodate up to 600 researchers. Just one-third of this capacity is currently available, and a small number of firms are located at the site.

Supporting IP protection and innovation finance

In 2014, the government established the Institute of Intellectual Property (IPIL) to raise awareness on IP. The objectives of IPIL are to develop and provide support services on IP issues to public and private organisations; to train and raise awareness on IP issues; and to conduct studies to advise the government on IP issues. IPIL was conceived by the Intellectual Property Office of the Ministry of the Economy; the new Institute will employ most of the human resources of the Centre de veille technologique (CVT) located within LIST.

Several bodies offer financial capital for firms or entrepreneurs willing to invest in innovation:

- The *National Credit and Investment Company* (SNCI) provides loans to firms in Luxembourg. SNCI provided loans for innovation activities until 2009; in 2014, it introduced new funding instruments to provide innovation loans to SMEs that go beyond R&D efforts related to technological activities. The RDI Loan extends credit to eligible SMEs of up to EUR 250 000 per project and 40% of eligible expenses.
- The *Loan for Innovative Enterprise* targets firms of less than 8 years of activity. It can fund up to 1.5 million EUR and 35% of the total cost of the project;
- The *Luxembourg Future Fund* of the SNCI, with capital of EUR 150 million, is managed by the European Investment Fund, and targets SMEs.
- The *Life Sciences Fund* is linked to government actions targeting the biotechnologies and plans to invest 80% of its funds in start-ups.
- The *Luxembourg Business Angel Network* (LBAN) is a non-profit organisation that promotes angel investing and supports early-stage investments in Luxembourg. As is typical of business angel networks, LBAN brings together private investors, early-stage funds and entrepreneurial ventures. LBAN is governed by a board of individuals from industry and is supported by the Luxembourg Chamber of Commerce.

Concluding remarks

The 2009 RDI law provided new possibilities for the government to support business R&D and innovation that appear to have helped rebalance the policy mix. At the same time, several aspects of the design and implementation of existing instruments could be improved. To begin with, the existing policy framework to promote innovation in the business sector lacks a clear strategic orientation. The rationales governing the choice of the specific instruments and the magnitude of their budgets are not explicitly stated. The instruments are not always – and not necessarily – aligned with government priorities (e.g. the sectoral action plans) and strategic goals: most of the programmes are open to all kinds of R&D and do not target specific sectors, with the exception of the Luxembourg Cluster Initiative – which, however, primarily provides business-support services, rather than implement ambitious innovation projects. While "sector-neutral" innovation support is certainly helpful to promote innovation in all sectors, a stronger alignment between business-innovation programmes and national research priorities could foster synergies between public research and business innovation, and upgrade the absorptive capacity of the business sector itself.

Furthermore, strengthening innovation performance in both existing and new companies requires using innovation policy instruments in ways that facilitate the accumulation of in-house innovation capabilities and a progressive extension of their ambition. The transition to rigorous evaluation and selection of project proposals on the basis of commercial viability and scientific and technological merit would help induce behaviour that would not have occurred in the absence of policy. However, this would require more administrative resources and capabilities, which may be difficult to bring about within current institutional arrangements. Delegating some implementation functions (notably funding) to an agency outside of the Ministry of the Economy would lead to a division of labour and potentially to more sophisticated programming and implementation, as is already the case in many countries with advanced innovation systems (see Box 4.5).

The range of services offered by Luxinnovation remains very broad; many of its activities are related to business coaching and business development rather than innovation. This distinguishes Luxinnovation from its counterparts in innovation-intensive countries, which typically fund ambitious innovation projects targeting businesses (Box 4.5). A shift in focus from business-development activities to funding competitive innovation projects may be a key step in raising the ambition of private companies' innovation activities. Depending on the scenarios, this would require closer co-operation between Luxinnovation and FNR in managing innovation grants and programmes, or transforming Luxinnovation into a fully-fledged innovation agency funding innovation programmes via competitive mechanisms. In both cases, Luxinnovation would need to acquire the necessary skills to perform these tasks. Luxinnovation would also need to be turned into a public organisation to avoid possible conflict of interest.

Last but not least, the system's rising resources and increasing maturity, together with the ambition to use innovation policy as a tool of economic diversification, call for changes in the way innovation policy is programmed and delivered. Linking government intervention to specific instruments and, as far as possible, measurable objectives, can improve the legitimacy of innovation policy and provide a common framework for discussion and policy development. While the existing policy mix is helpful to many firms, none of the business-innovation support policies described above have been evaluated. This makes it difficult to ascertain to what extent they are a good use of public resources, as well as assess the quality of the different instruments and understand why some are more in demand than others. In countries with a long history of innovation policy (e.g. the Netherlands), programming and instrument design is typically informed by past evaluations and adjusted to respond to evolving policy challenges. The long-term efficiency and effectiveness of innovation policy would benefit from introducing similar processes in Luxembourg. The imminent revision of the 2009 RDI law would provide a good opportunity for a round of evaluations, possibly performed by mixed teams of national and international experts.

4.5 Investing in public-sector research

Over the last decade, the Luxembourg government has increased funding of research carried out in the CRPs and University. It has also made new investments in research infrastructure, notably the Cité des Sciences at Belval. The Ministry of Higher Education and Research plays the leading role, providing block funding to the CRPs and University. This funding constitutes their largest source of income and is governed by a performance contract with each organisation (see Section 4.3). The FNR provides competitive funding,

directed through several schemes emphasising research excellence. While this funding has grown markedly in recent years, it accounts for just one-fifth of public spending on R&D (see Section 4.2).

Box 4.5. Examples of innovation agencies in Europe: Finland's Tekes and Research Council of Norway

Tekes

The Finnish Funding Agency for Technology and Innovation (Tekes) was established in 1983. It is one of the most important publicly funded organisations financing RDI in Finland: in 2014, it awarded a total of EUR 550 million in funding. The other key funding agency in Finland is the Academy of Finland (EUR 310 million budget in 2014), which mostly funds fundamental research projects. Tekes targets researchers and business organisations (including service companies) and adopts a broad definition of innovation that goes beyond R&D and technological breakthroughs. It has selected a few priority areas: natural resources and sustainable energies; digital systems and user-oriented products and services; and health and skills.

Every year, Tekes finances approximately 1 500 business research and development projects, and 500 public research projects at universities and other research organisations. It offers a diversified range of innovation-support services, from funding innovation projects to providing venture capital through Tekes Venture Capital Ltd. With a view to promoting international R&D co-operation, Tekes funds collaborative R&D projects and facilitates researcher mobility. It also has offices in six locations abroad. Tekes can finance R&D projects undertaken by foreign-owned companies registered in Finland; international companies with R&D activities in Finland do not need to have a Finnish partner to be eligible for funding. The financed project should, however, contribute to the Finnish economy.

Research Council of Norway

The Research Council of Norway combines the roles of a traditional research council with that of an innovation agency, funding a broad spectrum of research, from fundamental work in universities to product and process development in companies. The Research Council offers a wide range of activities targeting the business sector, from start-up support to funding for more advanced research projects and tax incentive schemes. Similarly to Luxinnovation, the Research Council offers assistance in finding the most suitable programmes for companies. The Division for Science is for promoting excellence in scientific research and the Division for Innovation for promoting excellence in innovation. They play similar roles to the FNR and Luxinnovation, but are part of the same organisation.

The Division for Science is responsible for the strategic development of Norwegian universities, university colleges and independent research institutes. It assigns competitive research grants by using scientific merit as the primary selection criterion. It is responsible for providing funding for national scientific infrastructure, as well as designing evaluations of scientific programmes.

The Division for Innovation is responsible for mobilising and funding research within and for Norwegian trade and industry. The Division analyses and develops strategies for trade and industry-related thematic areas, as well as for the innovation system as a whole. It administers the tax incentive scheme and open competitive innovation-funding programmes, EUREKA's Eurostars Programme and the industrial PhD schemes. Other programmes target specific sectors such as food, maritime operations, transport, ICTs, nanotechnology and biotechnology. The Division is also responsible for the Research Council's Centres for Research-based Innovation (SFI) scheme, which is designed to give a boost to the most outstanding Norwegian research groups that work in close collaboration with partners from national and international companies. Centres that receive SFI status serve to showcase Norwegian industry-oriented research and play an important role in providing an industry-relevant basis for doctoral studies.

Sources: Tekes website (www.tekes.fi); Research Council of Norway website (www.forskningsradet.no/en).

Luxembourg's small size means it is unable to pursue a wide range of research areas in the same manner as larger advanced economies. The areas pursued should have "critical mass", e.g. they should be of sufficient size and depth to produce very good or excellent research that is (for the most part) internationally visible. The government has also signalled that research should have high socio-economic relevance, and has placed considerable emphasis on public research-related valorisation activities. Public research should also contribute to diversifying Luxembourg's economy and reducing its dependence on the financial sector, through initiatives such as the Health Sciences and Technologies Action Plan.

Research priorities

The FNR conducted a foresight exercise in 2006-07 and identified several "national" research priorities targeting a small number of thematic areas. These are organised into five broad categories (Table 4.3) – innovation in services, sustainable resource management, new functional materials, biomedical and health sciences, and societal challenges – which have been used to concentrate funding in its largest funding scheme, the thematically oriented CORE programme. CORE is organised through annual calls, the first of which was launched in 2008, when CORE replaced the former thematic funding programmes of the FNR. Its main objective is to strengthen research capacities that contribute to creating critical mass and international visibility in the five priority fields. This critical mass is expected to provide the basis for public research to help generate sustained socio-economic and environmental benefits for Luxembourg. The programme's budget totalled EUR 73 million in 2008-10 and EUR 69 million in 2011-13; it is set at EUR 70 million for 2014-17.

Table 4.3. **FNR CORE programme thematic domains**

Innovation in services	– Development and performance of the financial systems – Business service design – Information security and trust management – Telecommunication and multimedia
Sustainable resource management in Luxembourg	– Water resources under change – Sustainable management and valorisation of bioresources – Sustainable building and bioenergy – Spatial and urban development
New functional and intelligent materials and surfaces and new sensing applications	– New functional and intelligent materials and surfaces
Biomedical and health sciences	– Regenerative Medicine in Age-related Diseases – Translational Biomedical Research – Public Health
Societal challenges	– Social and economic cohesion – Education and learning – Identities, diversity and interaction

Source: FNR website (www.fnr.lu).

Considerable debate is taking place in Luxembourg on the merits, meaning and status of FNR national research priorities, which do not perfectly align with the sectoral action plans and clusters promoted by the Ministry of the Economy – nor with the research areas pursued by the University and CRPs. While emerging strong research capabilities in the University and CRPs in some fields (e.g. biomedicine, ICTs and smart materials) indicate

good alignment, this is not the case in other fields (e.g. sustainable resources). Moreover, some areas of existing research competence in Luxembourg – notably law and mathematics, where the University has strengths – are excluded from FNR priorities. Some hold that FNR funding should better accommodate areas of research pursued by these actors; others counter-argue that the University and CRPs pursue too many research areas, and that some top-down prioritisation is necessary to create critical mass and visibility that will help achieve national socio-economic goals. The issue seems to be one of balance: given Luxembourg's small size and limited resources, prioritisation is essential; yet a national research-funding agency like the FNR should support a variety of projects, particularly given the uncertain nature of research. With this in mind, the FNR recently introduced the OPEN programme, a modest new project-funding scheme targeting researchers working in areas outside of the CORE thematic priorities.

The FNR priorities are now eight years old; during this time, the research landscape has radically transformed. They should be revisited as soon as possible, probably as part of the proposed national STI strategy process recommended earlier in this chapter (see Section 4.3). Selecting national FNR research priorities should involve a deliberative process including all the main stakeholders in Luxembourg, but the process should be lighter and considerably shorter than the foresight exercise carried out in 2006-07. Furthermore, while selecting national FNR research priorities should take into account the industry priorities set by the Ministry of the Economy and the institutional priorities of actors like the University of Luxembourg, they should not be fully aligned simply for the sake of neatness. Rather, public research actors will need to adjust to revised national priorities in their own internal prioritisation exercises.

It bears noting that the FNR accounts for just one-fifth of national public research funding in Luxembourg, and therefore has limited leverage over the research areas pursued by the University and CRPs. The bulk of public funding they receive is still channelled through Ministry of Higher Education and Research block grants, which they are free to allocate internally according to their own priorities. A more strategic alignment of University and CRP research profiles with national priorities would likely need incentivising. This could be done through "top-slicing" of block grants for specific priorities and/or channelling a larger share of public research funding through FNR thematic programmes. A national research assessment exercise, including criteria on excellence, relevance and critical mass, could also be launched. While such mechanisms would encourage the University and CRPs to consolidate their research profiles, they have their strengths and weaknesses and are likely to be controversial. They would need to be carefully considered as part of a wider debate on steering the research system.

Debates on priorities also extend to the types of support measures that are most appropriate for building and maintaining critical mass in a small variety of research fields; the current FNR portfolio of support measures – including those designed to attract leading and promising researchers to Luxembourg (see Section 4.6) – seems appropriate in this regard. There also appears to be flexibility to assign extra resources to a few chosen priority areas. For example, the FNR recently announced a new pilot scheme, the National Centres of Excellence (NCER) programme, which provides long-term funding to consortia of leading scientists to address ambitious scientific and socio-economic goals (Box 4.6).

Box 4.6. The National Centres of Excellence (NCER) programme of the FNR

The NCER programme aims to provide sustained support for strategic research areas that are expected to have a socio-economic return in the medium to long-term. The programme works by offering financial support for a trans-institutional collaborative research centre dedicated to solving a well-defined and relevant socio-economic question. To achieve this, the FNR supports the bundling of existing competences and reinforcing partnerships and networks between research groups in Luxembourg and abroad. In addition, the FNR attempts to leverage existing investments and steer future investment of institutions into the relevant research field in order to reach critical mass and an end goal with socio-economic value for Luxembourg. The first pilot NCER on the topic of "Early diagnosis and stratification of Parkinson disease" (see Box 4.12) addresses a significant problem for ageing populations in Western societies.

The NCER will run for an initial period of eight years, with a mid-term review and the possibility of one extension of three to four years. The FNR will provide a maximum EUR 1.5 million per year for the first funding period, e.g. EUR 12 million over eight years. It is also understood that the partner institutions will invest in the centre with a significant contribution (e.g. by appointing new professors, acquiring infrastructure). The funding covers all relevant expenses required for establishing the centre and its technology-transfer activities.

Source: FNR website (www.fnr.lu).

Valorisation

Academic engagement with industry involves multidirectional knowledge-related collaboration through formal (e.g. collaborative research, contract research and consulting) and informal (e.g. networking and exchanges at conferences and other forums) activities. Although sometimes measured through patenting and licensing of inventions, as well as academic entrepreneurship (e.g. spin-offs), valorisation does not only occur at the end of a research project or programme. Instead, it is the result of interaction between a variety of research and innovation actors at different stages of research and innovation.

Considerable effort is under way in Luxembourg to improve the valorisation capabilities of public research actors and provide adapted institutional and physical infrastructures. Many of the relevant infrastructures for promoting spin-offs and IP from public research, including Technoport and the House of Biohealth, are already – or will be – located in Belval (see Section 4.4). Co-location in Belval should provide an opportunity for researchers, academics and students to interact and benefit from local knowledge spillovers. Other nascent structures promoting technology transfer and valorisation are hosted by the University of Luxembourg and the CRPs. Most have recently established technology-transfer offices that are intended to act as key contacts for researchers aiming to valorise the results of their research.

The FNR seeks to promote knowledge transfer from public-sector research to the business sector through collaborative research programmes involving P/PPs. For example, its two largest programmes, CORE and AFR, support P/PPs. The 2010 evaluation of the FNR highlighted weaknesses in its support of valorisation, which has since been incorporated as one of the main missions of the FNR. This has resulted in the recent launch of two new programmes: Proof-of-Concept (POC) to support translation of research findings into commercially viable innovations; and Knowledge and Innovation Transfer Support (KITS) to support improvements in research organisations' valorisation

infrastructures (Box 4.7). This is a promising development, but more could probably still be done. For example, all FNR panels could include industry representatives and other users (as happens in many other countries), and joint programming with the Ministry of the Economy targeting P/PPs could be introduced.

Box 4.7. **FNR programmes dedicated to valorisation**

Proof-of-Concept (POC)

The POC programme provides financial support to the University and CRPs to encourage translating high-impact research into commercially viable innovations. Its purpose is to bridge an existing funding "gap" between government-supported innovations that result from public-institution research and private sector-supported transformation of those innovations into commercial products. Through the programme, FNR invests in the pre-commercialisation of leading-edge technologies/concepts/products emerging from Luxembourg research organisations, including early-stage development projects, feasibility studies, simulations, working prototypes, further IP protection and strengthening, pilot concepts and devices of highly innovative nature, in order to facilitate soliciting private-sector funding and partnerships.

Knowledge and Innovation Transfer Support (KITS)

The objective of the FNR-KITS programme is to provide competitive funding to public research organisations in Luxembourg that will allow them to attract and integrate highly skilled professionals in the area of knowledge transfer. The programme is intended to contribute to reinforcing institutional units – such as technology-transfer offices – that engage in the strategic integration and operational implementation of knowledge-transfer activities, with the ultimate goal of generating economic and societal value through their research programmes.

Source: FNR website (www.fnr.lu).

Under the terms of the 2009 RDI law, the Ministry of the Economy supports public-private collaborative projects, which have recently grown in number (see Section 4.4). Luxinnovation also has several activities and programmes promoting knowledge transfer between firms and public-sector research organisations. It regularly organises networking events and actively helps businesses find the right research partners in the public-research landscape. It has a dedicated programme supporting innovative start-ups and assisting companies on IP matters. This programme extends to public research organisations, and Luxinnovation has a formal role in supporting the valorisation efforts of researchers and technology-transfer offices efforts (Box 4.8).

The performance contracts include valorisation indicators, e.g. on the number of patents, spin-offs, prototypes, contract research and licensing income. Given their low numbers and limited number of observations, these indicators do not indicate a clear trend. Moreover, they do not capture valorisation activities occurring through collaborative research, personnel exchanges, mobility programmes or other channels and forms of knowledge transfer that are equally important to innovation. This points to a strong need to broaden the concept of valorisation and improve its measurement. Box 4.9 briefly describes some pioneering work recently carried out in the Netherlands to develop indicators of broadly defined valorisation activities.

Box 4.8. The role of Luxinnovation in supporting valorisation in the University and CRPs

To support and assist public research organisations with implementing their valorisation strategy, Luxinnovation has developed a range of services based on the following activities:

- contract support: establishment of collaborative research projects, which can involve contract negotiations pertaining to valorisation and may require specialised support
- information and awareness-raising activities focusing on valorisation issues and the protection of IPR
- identification of research results
- initial evaluation of the market potential and of the IP precedence of individual research results
- assistance throughout the process aiming to protect IP
- support for the socio-economic exploitation of research results: identification of and negotiation with potential partners, comprehensive support for the creation of spin-offs and the development of a business plan, identification of potential sources of public or private funding
- establishment of networks of national and international technology-transfer and valorisation experts
- provision of documents and procedures relating to technology transfer and valorisation.

Source: Luxembourg Portal for Innovation and Research (www.innovation.public.lu).

Box 4.9. Indicators for valorisation – experience from the Netherlands

In 2010, the Dutch government commissioned Technology Foundation STW, the Rathenau Institute and Technopolis to develop a list of generic indicators to measure valorisation performance. The indicators had to be applicable in a wide variety of settings, on several levels and for a variety of evaluation goals. The authors soon discovered that there was no ready-made set of indicators matching the broad definition of valorisation. They were also critical of the use of "number of patents" as an indicator of valorisation, arguing that the broader societal and economic use of scientific knowledge needs to be accounted for. They further argued that greater attention needed to be paid to the valorisation "process" (viewed as a process of interaction during *all* stages of research, rather than just the transfer of knowledge at the end of a research project) when attempting to measure valorisation performance, rather than simply counting "outputs". Combining quantitative and qualitative indicators, the study proposed a comprehensive four-dimensional framework that could be applied to various situations, including research universities, Dutch universities of applied sciences and a research council's thematic programme.

Since its publication in 2011, the framework has been used in a variety of ways – including by the Netherlands Organisation for Scientific Research and the Netherlands Enterprise Agency – and has been discussed in the Dutch parliament. It is credited with having moved valorisation-measurement discussions away from quantitative indicators of researcher and research organisation performance to a broader, more process-oriented approach that includes other actors (van Drooge and Vandeberg, 2013). Indeed, inspired by this study and by a European Commission (2011) report on a composite indicator for knowledge transfer, the Association of Universities in the Netherlands and the Vereniging Hogescholen have agreed with the government to develop a broader set of valorisation indicators based on their experience of types of valorisation in different areas of research. A well-balanced and tested set of indicators is expected to be ready by 2016.

Sources: Rathenau Institute and STW (2011), *Valuable – Indicators of Valorisation*; van Drooge and Vandeberg (2013), "Valuable – understanding valorisation".

All in all, while these efforts appear to be bearing some fruit, the impact of valorisation activities seems low by most accounts. This is not surprising, given that valorisation-minded policy has only gained momentum over the past decade. It is even less surprising considering that the economic impact of most *measurable* traits of valorisation (e.g. spin-offs and patents) is weak even in advanced innovation systems, where valorisation mostly occurs in the form of unmeasurable spillovers from training, collaboration and human-resource mobility. It is important to ensure that the valorisation strategies of funding agencies and research performers are realistic with respect to private-sector demand for public research. There is always a danger of placing too much emphasis on knowledge supply-side measures when there are persistent bottlenecks in the capacities and behaviour of parts of the business sector. Moreover, valorisation policy should not focus solely on research commercialisation, but also target the contribution of public research to clinical practice, public regulation, etc.

The Health Sciences and Technologies Action Plan

The Health Sciences and Technologies Action Plan (commonly referred to as the "biomedical initiative") was announced by the government in mid-2008. Like other sectoral action plans (see Section 4.4), it originated in the Ministry of the Economy, but is a joint initiative with the Ministry of Higher Education and Research and Ministry of Health. It aims to position biomedicine as a key innovation driver to foster economic diversification. It is notable for the significant amounts of investment made – in excess of EUR 100 million over 2008-13 – and the fact that Luxembourg previously lacked substantial research and innovation capabilities in biomedicine.

At the time of its launch, the government gave multiple rationales for the initiative, including the need to improve Luxembourg's research capabilities through partnerships with leading international research centres; reduce the costs of the health system through new therapeutic approaches; and promote economic development by creating new firms and attracting existing firms from abroad. The government selected molecular medicine as a niche. It based its decision on the fact that given its small size, Luxembourg has to specialise and be selective in its research; patents are likely in this very recent and emerging field, allowing the country to be at the cutting-edge of scientific and technological development; and developing non-invasive medical devices and technologies promises to be quicker than producing conventional drugs. While these criteria seem well chosen and compelling, the limited number of related firms and pre-existing research capabilities in Luxembourg also makes the choice of biomedicine rather risky.

At the outset, the three pillars of the initiative were the LCSB in the University of Luxembourg, the IBBL and the Lung Cancer demonstrator project hosted at CRP Santé. About a year after the government announced the initiative, the collection of lung cancer samples began (in September 2009) and a new building to host the IBBL opened (in October 2009). The LCSB was founded in 2009 and its facilities opened officially in September 2011 in Belval. While the Lung Cancer demonstrator has since been subsumed into another initiative, both the LCSB and IBBL (see Box 4.10) are now well-established in the Luxembourg research landscape.[4] The LCSB has been particularly successful and sends an important signal to other research actors in Luxembourg: four years after launching, it is now a large centre already located in Belval (rather than in a prefabricated temporary structure). It constitutes a key research actor, ambitious, visible and rapidly growing.

Box 4.10. **The Integrated BioBank Luxembourg (IBBL)**

The plan to build the IBBL materialised in 2008, as part of the Luxembourg Health Sciences and Technologies Action Plan. The IBBL is an infrastructure designed to boost (bio)medical research and improve links between the research world and healthcare professionals and patients by storing/analysing various kinds of samples (tissue samples, body fluids, DNA, etc.). According to its website, its stated mission is to provide "high-quality biospecimens and associated data, foster scientific excellence, catalyse partnerships and support research that translates scientific discoveries into new healthcare solutions". Its strategic goals are to establish biobanking in Luxembourg; enhance the technological services available to the research community; support the four priority research programmes in the personalised medicine initiative in Luxembourg (cancer, diabetes, Parkinson's disease, and a normal population cohort); and seek partnership opportunities. The IBBL was conceived as a tool to support the other projects of the action plan (e.g. the LCSB and the lung cancer project).

The Translational Genomics Research Institute (TGen) in Phoenix, Arizona, a leader in the field, assisted in the creation of the IBBL. TGen aims to translate genomic discoveries quickly into disease diagnosis and treatment, thus combining discovery, translation and clinical applications. Luxembourg largely adopted this philosophy. In 2010, sample collection began, the building of the IBBL was inaugurated and the first CEO was appointed. By 2013, the IBBL contained around 200 000 samples from 10 000 donors, and numbered 26 international partners. Among its current clients and partners are hospitals (e.g. the Hospital of Helsingborg, University Hospitals of Geneva, and several hospitals in Luxembourg), actors involved in clinical trials (e.g. Precision Bioservices and Breast International Group), universities (e.g. University of Luxembourg and University of Magdeburg) and around a dozen companies. The IBBL has 37 staff members, including 7 researchers. In 2014, as part of changes introduced by the new CRP law, the IBBL moved into CRP Santé and is now part of the LIH. It continues to have extensive autonomy, however, thanks to its own performance contract with the Ministry of Higher Education and Research. Over the four-year course of the current contract (2014-17), the IBBL will receive EUR 30.8 million from the government.

The biomedical initiative revolved around a strategic collaboration with several leading US institutes: TGen in Phoenix, Arizona; the Institute for Systems Biology in Seattle, Washington; and the Partnership for Personalised Medicine, a collaborative effort between Arizona State University in Phoenix and the Fred Hutchinson Cancer Research Centre in Seattle. These institutes received funding to advise and train researchers working in Luxembourg, thereby providing considerable "scientific capital". They also provided considerable "symbolic capital": Hiraoki Kitano from the Systems Biology Institute in Tokyo – which was also associated with the initiative– and Leroy Hood from the Institute for Systems Biology are generally seen as the "founding fathers" of systems biology, and their centres are considered as leading institutes. Their association with the biomedical initiative lent it immediate recognition, as well as international visibility and connectivity.

The initiative's objective of improving research capabilities in Luxembourg appears to be well on track. However, the partnership with US institutes reportedly cost tens of millions of euros – meaning that repeating such an expensive initiative in other fields would require careful consideration. The economic and health benefits of the biomedical initiative have yet to be realised, and expecting companies to be created or attracted at a fast clip is not realistic. While research should aim to make socio-economic contributions, this takes time, and many contributions from such investments are indirect and difficult to measure. The government therefore needs to have realistic expectations regarding its

returns on investment. Furthermore, scholarly research suggests that only a small share of spin-offs ever become successful, in the sense that they become SMEs rather than large firms and are more commonly targets for acquisition by other firms; "failures" are part of the process. Luxembourg's industrial base and attractiveness in the biomedical area are still low. While new infrastructures, such as the House of BioHealth at Belval, could help attract firms, the government may need to offer other incentives to entice more firms to locate in Luxembourg.

Similarly, realising health benefits takes time and requires close co-operation between researchers and clinicians (Box 4.11). Yet a lack of tradition and history in the field means that linkages between government, industry, clinical practice and research remain weak, likely hampering health innovation and adoption in clinical settings. Clinical research needs to be further developed and supported in Luxembourg hospitals, with a view to providing new treatments to local patients and, ultimately, international markets. A promising recent development in this regard is the establishment of a translational clinical research centre on Parkinson's disease (Box 4.12), but more needs to be done. For example, the Ministry of Health should better co-operate with the Ministry of Higher Education and Research to develop new professional schemes (e.g. secondments, detachments and sabbaticals) between hospitals and research centres to improve knowledge transfer and co-operation. Furthermore, in order to exploit opportunities stemming from the biomedical initiative, more attention should be paid to the regulatory framework governing health technologies, e.g. genetic testing. Innovations in the life and health sciences are generally highly sensitive to ethical, legal and regulatory frameworks. The Ministry of Health needs to take the lead in this area, but has so far played a rather minor role in the initiative.

The biomedical initiative is still in its early phases. While it has already reaped successes, many challenges lie ahead. Similar initiatives could be launched in other areas, but should aim to be less costly. They could also aim to partner with "excellent" or "very good" research groups abroad. The NCER programme of the FNR could provide a useful platform for launching such initiatives.

Cité des Sciences at Belval

When Luxembourg's last operational blast furnace was shut down at Belval in 1997, an area of 120 hectares became available for redevelopment. It is now one of the largest and most ambitious current urban-renewal projects in Europe, with a budget of nearly EUR 1 billion. The large-scale infrastructure development underway at the site is an important milestone in continuing efforts to consolidate and upgrade the public research system. It includes the Cité des Sciences complex, which aims to assemble in one place most of the University of Luxembourg and the bulk of CRP facilities (including LIST and LISER). It is expected to become the study and work place of about 7 000 students and 3 000 researchers and lecturers before the end of the current decade. Newly built facilities will also house private firms involved in research, as well as support P/PPs, e.g. at the Technoport and nearby House of BioHealth (see Section 4.4).

The government hopes co-location at Belval will yield several benefits. To begin with, it should enhance critical mass in those research areas where different groups will be sharing buildings and facilities. Opportunities may also arise in terms of interdisciplinarity: some institutions could be reconfigured once researchers start working in the same buildings, and previously unforeseen possibilities for co-operation may emerge. Belval also offers unique opportunities to raise the international visibility and attractiveness of research and innovation activities in Luxembourg.

Box 4.11. **Lost in translation? The promise of translational medicine**

Translational medicine has been hailed as a new "paradigm" and one of the most important developments in medicine since the beginning of the 21st century. The essential idea of translational medicine is to create links between basic research and clinical research, between researchers working in a laboratory and patients and doctors in a hospital. The current links "from bench to bedside" are deemed problematic. They are seen as too time-consuming (many years elapse from the discovery of a new molecule or therapy to its use), too difficult (several disciplines, institutions and professions need to collaborate and co-ordinate their efforts) and too expensive (the development of a molecule costs millions of euros, and only about 5% of new molecules eventually become marketable products.) This is why political and academic actors are actively fostering translational medicine by establishing translational research centres to help scientists collaborate with doctors and translate knowledge from the laboratory into applicable innovations and products.

Translational medicine is a growing area, especially in the United States. The National Institute for Health was the first (through a Roadmap in 2003) to establish translational research centres to help scientists bring new products from the laboratory into useful innovations. Several European networks have since been created, such as the European Society for Translational Medicine and the European Infrastructure for Translational Medicine. There are also several initiatives at the national level in Europe. In the United Kingdom, for example, there is the Institute of Translational Medicine at the University of Liverpool, and initiatives at the University of Cranfield and Imperial College London; and the Wellcome Trust has launched its Translational Medicine and Therapeutics Programmes for clinicians. In Germany, initiatives include the Translational Platform and the Clinical Trial Centre at the University of Cologne, a master's programme in translational research at the University of Heidelberg and a research centre in Leipzig, to name but a few. France has Centres of Clinical Investigation, the Laboratory of Translational Research at the Institut Gustave Roussy, the launch of physician training by the National Cancer Institute and the launch of the Servier Prize for Translational Medicine. In many universities across Europe, research units have been created, and courses launched.

Translational medicine is sometimes described as "lost in translation" owing to several barriers: the difficulty of moving from a model (animal, in vitro...) to humans; the fact that diseases are not simple, but heterogeneous and complex objects; the presence of different ethical and practical norms; language and cultural barriers; the incompatibility of databases and samples; and the lack of qualified people and support. For translational medicine to be able to move from bench to bedside (and vice-versa) in Luxembourg, all these barriers need to be addressed.

Box 4.12. **National Centre of Excellence in Research on Parkinson's disease**

The NCER-PD (National Centre of Excellence in Research on Parkinson's disease) was approved for a 2015 launch and will focus on improving the early-stage diagnosis on Parkinson's disease (PD) and the stratification of PD patients – two of the most important scientific and clinical challenges in this field. All major stakeholders of biomedical research in Luxembourg are involved in the NCER-PD programme: the University of Luxembourg with the LCSB as the co-ordinator, the LIH, the IBBL and the Centre hospitalier de Luxembourg.

One long-term objective of the NCER-PD programme is to recruit and analyse a cohort of PD patients from Luxembourg and clinical centres in neighbouring countries to help identify predictive and progressive disease biomarkers. Several shorter exploratory projects will accompany the programme, notably the development of a joint platform with the National Institutes of Health in the United States to host and analyse whole genome-sequencing data from several international PD cohorts.

This is a major novelty for Luxembourg, as it marks the first time the FNR launches a Centre of Excellence programme with such unprecedented budgetary means. It also presents an opportunity for the country to promote its expertise in systems biology on an internationally competitive level and build a translational clinical research centre for PD, with a direct return to society.

Source: FNR website (www.fnr.lu).

The project has not been without the problems typical of large infrastructure projects. First, it is some years behind schedule, which has created considerable uncertainty, especially for the University. Second, concerns have been voiced about the site's apparent lack of space to house the research groups that are supposed to move there over the next few years. This jeopardises Belval's original aim of co-locating researchers working in similar areas, independently of their organisational affiliation, and instead risks raising tensions about which group should get the most space. It appears that further infrastructural investments will be needed for the initiative to deliver on its aims of creating critical mass and excellence in chosen research areas. Third, the quality of public-transport links with Luxembourg City is also under question, which could undermine efforts to develop a vibrant knowledge community at the site.

4.6 Strengthening R&D skills

The expanding public research system has created strong demand for research staff. Luxembourg's raised ambitions mean it needs to attract high-calibre researchers from around the world. Reflecting these challenges, policy places considerable emphasis on strengthening the human-resource base for research. This chiefly involves a mix of nurturing "home-grown" skills – through PhD and post-doctoral training programmes – and attracting leading and promising young researchers from abroad to Luxembourg. Both policy orientations have been successful, though some important issues remain, as discussed below. Attracting young Luxembourgers to research careers is still a major challenge, as is redressing serious gender imbalances in the researcher population.

Nurturing research-skill development

The national R&D base can expand through training PhD and post-doctoral researchers. Doctoral training in Luxembourg has evolved considerably over the last decade. The University of Luxembourg awarded its first PhD degrees in 2006 and established its doctoral schools in 2012. The performance contracts of the CRPs include targets on PhD students, and doctoral training is now a formal objective enshrined in the 2014 CRP law (see Chapter 3). Luxembourg numbered an estimated 600-700 ongoing doctorates in the 2013-14 academic year, around three-quarters of which were taking place at the University of Luxembourg (or in collaboration with the University).

More than half of the ongoing doctorates in Luxembourg are funded by the FNR: approximately 40% are funded through the AFR grant scheme, and 10% through other various FNR programmes. The AFR scheme supports PhD and post-doctoral training (up to four years for a PhD and two years for a post-doctoral student) both in Luxembourg and abroad. It also provides incentives for joint public-private research partnerships. The AFR has no thematic focus and is open to researchers of all nationalities. However, if the research training takes place outside Luxembourg, eligible applicants must be either nationals or residents of Luxembourg for more than five years. Grants amount to around EUR 40 000 a year for PhDs and EUR 57 000 a year for post-doctoral students. In 2013, the FNR funded 99 AFR PhDs and 49 post-doctoral places at a cost of EUR 29 million.

The AFR was evaluated in 2010. The evaluation highlighted several positive aspects, including the scheme's emphasis on scientific quality; the sophisticated selection procedure for AFR candidates; the independence the scheme allows its beneficiaries; and its social security benefits. It also identified shortcomings, notably the assignment of funding to pre-existing projects that had been rarely designed and written by the direct beneficiaries themselves; and the complex – and thus time-consuming and sometimes opaque –selection procedures. The evaluators recommended modifying the scheme so as

to create a loose framework that would leave room for bottom-up initiatives meeting the needs of the respective scientific communities, individuals and organisations. They also recommended simplifying application procedures. The AFR took these recommendations on board: it has simplified and shortened procedures with lighter call documents, selection and monitoring. In addition, changes in the 2014 FNR law have allowed the FNR to introduce a new collective doctoral scheme, known as PRIDE, to better support bottom-up initiatives. PRIDE will replace most – though not all – of the doctoral funding currently transiting through the AFR scheme. A total of 120 PhD grants will be awarded in the 2015 call.

Through PRIDE, the FNR awards a block of non-nominative PhD grants to a team of supervisors grouped around a coherent and competitive research programme. This provides greater flexibility for research organisations to allocate PhD grants to individual candidates of their choice. Proposals in all fields of research and technological development are eligible for funding. However, the scheme targets research teams that already have a track record in doctoral training and wish to consolidate and develop long-term doctoral training programmes around strong research themes. An overarching research theme serves as the foundation of a coherent research and training programme. The research programme should link its thematic and/or methodological focus areas in a manner that yields excellent topics for doctoral theses, while suitably addressing relevant issues. Innovative approaches – whether interdisciplinary, intersectoral (e.g. co-operation with companies or other users of research) or international partnerships – that provide a competitive advantage over competing groups are encouraged.

The Doctoral Training Unit (DTU) is the applying entity under the PRIDE programme. A DTU should be made up of a group of at least eight supervisors from one or several host organisations; each supervisor requests funding for at least one four-year PhD position. The Unit should be co-ordinated by an internationally recognised scientist belonging to the co-ordinating research organisation, and be based on a coherent and competitive research programme. It should present a joint strategy for research and PhD training, and ensure an innovative high-quality training environment. Significantly, a DTU does not need to be a formally established entity within any single research organisation; rather, it is primarily defined by its research programme. While all PhD candidates funded through PRIDE are expected to be enrolled in a doctoral programme or school of a degree-awarding institution (either the University of Luxembourg or an academic institution abroad), the doctoral programme or school is not to be equated with the DTU. Rather, different PhD candidates recruited by a given DTU can be affiliated with different doctoral programmes (or even different universities), e.g. an interdisciplinary and/or international research programme.

PRIDE represents a significant development for the FNR and Luxembourg's research system, as its selection criteria implicitly focus doctoral funding on a limited number of fields of excellence with critical mass. Where this critical mass does not exist in a single research organisation – which seems to be the case for many research areas – the scheme encourages collaboration between the research organisations within DTUs. This should lead to greater joint research programming between the University and CRPs and – thanks to scale effects – raise the international visibility of research activities in Luxembourg. Moreover, national public research organisations can use PRIDE to strengthen their collaboration with outstanding international academic research institutions. Such collaborations should facilitate the recruitment of excellent PhD candidates, promote high-quality research in Luxembourg and open attractive career perspectives for PhD candidates.

Attracting leading and promising researchers to Luxembourg

The performance and ultimate success of Luxembourg's research system will depend on the calibre of researchers it is able to attract from abroad. As a young research system with little visibility and reputation, Luxembourg faces challenges in attracting leading researchers. Economic incentives – particularly better pay and access to research funding – can help, but high-calibre researchers also seek high-quality research infrastructure and opportunities to work with other leading scientists. While these cannot be developed overnight, Luxembourg has already made some good progress and is moving in the right direction.

The research workforce in Luxembourg is already overwhelmingly foreign, though the vast majority are from the Grande Région. To realise its ambition, Luxembourg must attract high-calibre scientists from further afield. RTO-type organisations, like the CRPs, are traditionally less attractive than universities to leading international researchers, though there are exceptions, depending in part on the institutional configuration of national innovation systems and the roles played by RTOs. Given the youth of the University of Luxembourg, it generally lacks research visibility and continues to face difficulties in attracting high-level research professors. The interdisciplinary centres – which have rapidly become internationally visible and increasingly attractive to foreign researchers – are the exception. They have benefitted from the leadership of internationally renowned researchers with good prior experience of establishing such centres and sufficient reputation to attract other leading researchers.

Other issues that conspire against attracting high-calibre researchers include limited space and facilities, at least until Belval comes on stream; certain immigration rules that prevent non-EU nationals from remaining in Luxembourg after completing their PhDs; and limited career routes available for the most promising young researchers. In that respect, Luxembourg should develop clear research-career routes (including tenure tracks) to improve its attractiveness to the most promising researchers. This will likely require developing a portfolio of schemes for different career stages, administered by research-performing organisations and the FNR.

The FNR has two dedicated programmes to attract leading scientific talent to Luxembourg:

- PEARL is designed to attract leading researchers to Luxembourg. Beneficiaries are offered a research grant for five years, which covers all aspects related to the development of a research programme, including major research equipment, infrastructure and data collection. The programme's budget during 2011-13 was EUR 22.5 million; it is set at EUR 25 million for 2014-17. The allocated budget for 2011-13 was not entirely spent – an indication that attracting leading talent to Luxembourg remains a challenge. The programme selected on average one or two candidates a year (corresponding to EUR 3-4 million per beneficiary), to be recruited by either the University of Luxembourg (which managed to recruit four candidates between 2009 and 2013) or the CRPs (CRP Henri Tudor, CRP Santé and CRP Gabriel Lippmann each recruited one candidate over the same period). The recruiting research organisation is expected to allocate matching funds to the FNR grant. The assessment is based on the scientific value of the proposal, as well as its alignment with FNR research priorities and the strategic orientation of the recruiting institution.

- ATTRACT is designed to attract young researchers to Luxembourg. It works in a similar manner to PEARL, but targets young researchers with two to eight years of professional experience since completing their PhD. It allocates individual grants of up to EUR 2 million for five years. After the grant ends, the beneficiary, if successfully evaluated, can obtain a tenured position in Luxembourg. The programme's budget totalled EUR 6 million for 2006-10 and EUR 9.1 million for 2011-13; it is set at EUR 10 million for 2014-17. ATTRACT applications must be submitted jointly by the hosting institution and the young researcher.

Several initiatives are in place to share information with non-residents about working as a researcher in Luxembourg. The online portal EURAXESS Luxembourg[5] provides information and assistance to foreign researchers who want to relocate to Luxembourg or apply for positions in the country. The EUSAXESS Service Centre also provides assistance on practical mobility matters. EURAXESS Luxembourg also issues a brochure, *Foreign Researcher's Guide to Luxembourg*, with extensive coverage of the national STI system and FNR programmes, as well as practical information about visas and living conditions in Luxembourg.

Addressing gender gaps among researchers

Gender imbalance is an issue: just 24% of researchers in Luxembourg are women – one of the lowest levels in the OECD. The situation is especially unbalanced in the business sector (11%), but less so in the CRPs (36%) and the University (39%). Luxembourg's industrial and research specialisation partly explains the low levels of female researchers: many of the industries and research fields that are prominent in Luxembourg tend to have low numbers of female researchers in all countries. The scope for redressing the gender balance might therefore be limited, though Luxembourg could still perform better than it currently does.

There are no public policy initiatives currently addressing this issue, which is unusual for an OECD country. Learning from international experiences, the government should consider introducing a national initiative to promote entry of more women in scientific fields in Luxembourg. Given the systemic nature of the gender gap, such an initiative could be led jointly by the Ministry of Higher Education and Research and the Ministry of the Economy, and address both the public and private sectors. It would need to actively involve research-performing organisations – researchers' employers – and the FNR, which could incorporate gender-related incentives into some of its instruments. The Ministry of Higher Education and Research should also explore how the performance contracts could be used to promote better gender balances in the University and CRPs.

Attracting young Luxembourgers to research careers

Attracting young Luxembourgers to science careers or to entrepreneurship is difficult because of competing career options in areas such as finance and the civil service, which are perceived as more attractive. The FNR runs several programmes to improve public understanding of science and promote science among students of all ages. These programmes particularly focus on increasing the attractiveness of research careers to Luxembourg's youth. The FNR has conceived a number of initiatives:

- Go for Science is a network where participants from the University, secondary schools, primary schools, after-school care, museums and non-profit associations meet to exchange and get ideas for study workshops, hands-on experiments and school-project weeks.

- ProScience where all major public research actors, as well as the Ministry of Education and the Service national de la jeunesse (the National Youth Service), communicate in order to facilitate the organisation of promotional activities and increase the University's and CRPs' support for promoting scientific culture.
- Measures for young scientists include the information website www.science.lu, the school contest GENIAL!, the Science Festival, the Researcher's Days, Mister Science, Searching for Researchers, Researchers in School and a variety of offers for children.

4.7 Supporting international knowledge linkages

Luxembourg's economy is highly internationalised, not only in traditional manufacturing industries but also in the service sector. A large part of the workforce consists of daily commuters from neighbouring countries. Much of private-sector research is performed by firms that are turned towards international markets, and the vast majority of researchers in the CRPs and University are foreign.

Participation in international (global) science and innovation networks is a crucial requirement for all advanced innovation systems, and even more so for small-sized economies like Luxembourg's. National programmes increasingly promote internationalisation of research and innovation activities, especially where public research actors are concerned. Internationalisation is one of the main objectives of the FNR and Luxinnovation (as indicated in the latest performance contracts 2014-17), and the CRPs and University are increasingly evaluated according to indicators that take into account participation in international (European) programmes. However, while global science and innovation networks are important to Luxembourg, so are also closer-to-home cross-border knowledge spillovers. In terms of contract research and talent recruitment, for example, Luxembourg-based firms are well-placed to benefit from major academic resources located in Aachen, Karlsruhe, Stuttgart, Nancy, Strasbourg, Liege, Louvain and Eindhoven.

Programmes targeting public-sector research

Several FNR programmes promote international research linkages. The programmes related to individual researchers are perhaps the most visible; they include PEARL, which aims to attract established researchers to Luxembourg, and ATTRACT, which targets young researchers (see Section 4.6). Created in 2012, the INTER Mobility programme promotes two-way scientific exchanges between research groups located in Luxembourg and abroad. The programme also funds secondments from private organisations, although the beneficiary should be a public research organisation located in Luxembourg. The programme has no thematic or geographical limitations. The total duration of stays abroad ranges from six weeks to one year and may be split over a three-year period. In 2012-13, the INTER Mobility Programme funded seven projects for a total cost of EUR 200 000 (FNR, 2014). Finally, the AFR programme, which is one of the most important instruments of the FNR in terms of funding volume, supports PhD and post-doctoral training in Luxembourg and abroad.

The FNR has also signed bilateral and multilateral agreements with a number of foreign research-funding agencies to support international research collaboration (Box 4.13). It is currently negotiating additional partnerships to expand co-operation with a larger set of countries.

Box 4.13. International funding partnerships of the FNR

Bilateral agreements of the FNR include partnerships with funding agencies in the following countries or international organisations:

United Kingdom: thanks to a bilateral agreement with the Research Council UK (RCUK) signed in 2013, researchers affiliated to the CRPs and University of Luxembourg may submit joint research proposals with colleagues in the United Kingdom. Bilateral projects must be submitted to one of the UK Research Councils and need to identify the most suitable RCUK funding instrument.

Germany: the FNR and the German Research Foundation signed a co-operation agreement in 2009 to facilitate common research projects. Funding is limited to three-year joint projects. The funding proposal must be submitted to the country where the project leader is located. The proposal is evaluated by the funding agency in that country and if accepted is co-funded by the two countries.

European Molecular Biology Laboratory (EMBL): the FNR and the EMBL have signed an agreement to jointly fund bilateral research projects. Submissions may be addressed to the CORE programme of the FNR, which proceeds with the evaluation.

Switzerland: the FNR and the Swiss National Research Foundation signed a bilateral agreement in 2010. The project proposal must be submitted to and is evaluated by the funding agency of the lead research team. Funding is limited to three-year projects. Proposals from lead teams in Luxembourg must be submitted through the CORE programme.

Austria: the FNR signed an agreement with the Austrian Science Fund in 2012. As with Germany and Switzerland, the proposal needs to be submitted to the funding agency of the lead research team, which evaluates the proposal. Funding from the two agencies is limited to three-year projects. Proposals from Luxembourg lead teams must be submitted through the CORE programme.

France: the Centre national de la recherche scientifique (CNRS) and the FNR offer three instruments to support joint research projects: i) the International Programme for Scientific Co-operation funds joint research projects of CNRS and public researchers in Luxembourg; ii) the European Associated Laboratories initiative allows CNRS and Luxembourg public researchers to jointly manage projects. Eligible costs covered are mobility expenses and training fees; and iii) the European Research Networks initiative is a network of researchers from the CNRS, Luxembourg and third countries. Eligible costs are mobility expenses and training fees. For all the joint programmes, FNR support is limited to the same amount provided by the CNRS. In addition, the Agence nationale de la recherche (ANR) and the FNR signed a co-operation agreement in 2013. Joint proposals are submitted for evaluation to the ANR; the FNR co-funds accepted projects.

Poland: The FNR signed an agreement in 2011 with the National Centre for Research and Development to co-fund bilateral projects related to innovation in services. Related research proposals must be submitted to the FNR within the CORE Programme. The FNR evaluates the proposals.

Belgium: The Research Foundation Flanders (FWO) and the FNR signed an agreement in 2009 to simplify the submission procedure of bilateral research project proposals. The FWO receives and evaluates the proposals. Selected projects are funded for four years. The FNR has also signed an agreement with the Belgian Federal Science Policy Office within the framework of the Stereo III Earth Observation project, which focuses on monitoring the Earth ecosystem, risk management and epidemiology.

Between 2011 and 2013, 33 bilateral projects were selected, totalling EUR 11 million in funding. In addition, the FNR is negotiating agreements with the Research Council of Norway and is considering the possibility of establishing partnerships with funding agencies in Singapore and Turkey. The FNR announced a collaboration with the US National Science Foundation (NSF) on "Catalyzing New International Co-operations", which provides co-funding for joint research projects between Luxembourg research teams and NSF-funded researchers. Additional FNR multilateral project-funding agreements include the Ambient Assisted Living Joint Programme, the European and Developing Countries Clinical Trials Partnerships, the European Research Area Network, EUROSTARS and the Material World Network – NSF Materials.

Source: FNR website (www.fnr.lu).

Participation in European programmes

According to the sixth monitoring report on the Seventh Framework Proposal (FP7) (European Commission, 2013), the success rate of Luxembourg research proposals in FP7 (covering 2007-12) was 19.2%, below the EU average of 21.7%. Innovation-intensive European countries such as the United Kingdom (23.2%), Germany (23.8%), Denmark (24.2%), France (25%) and the Netherlands (25.4%) performed better than Luxembourg. The success rate calculated in terms of share of awarded funding is even lower for Luxembourg (12.5%), below the EU average of 19.3%. Innovation-intensive countries, e.g. Germany (23.1%), Denmark (22.6%), France (24.1%) and the Netherlands (23.5%), are performing above average.

Among public research organisations, the University of Luxembourg was by far the largest recipient of EU FP7 funding (EUR 11.7 million) in 2007-12, followed by CRP Henri Tudor (EUR 2.6 million) and CRP Santé (EUR 1.7 million). Large enterprises attracted EUR 16.5 million, while SMEs attracted EUR 8.5 million. With respect to thematic research areas, ICT projects attracted 34% of EU funding, followed by security (13%) and health (11%).

The University of Luxembourg was awarded a European Research Council Consolidator Grant (assigned to consolidate an individual researcher's pre-existing research effort or team) in early 2015 in the field of material physics. This is the first University-based European Research Council grant and is seen as a successful result of the policy of high-level international recruitments at the University of Luxembourg.

Luxinnovation acts as the National Contact Point in Luxembourg for European research and innovation programmes. It manages the Fit4H2020 programme, which promotes participation of Luxembourg companies in Horizon2020 by covering some or all of the costs incurred in preparing and submitting a proposal. The amount granted may not exceed EUR 40 000. The latest available evaluation of Luxinnovation, carried out in 2010 when Luxembourg's participation rate in European programmes was even lower than it is today, criticised the lack of co-ordinated activities to promote participation in European programmes. It also pointed out that the University and CRPs considered Luxinnovation's technical support too generic to provide real value-added to researchers. The same evaluation showed that Luxembourg's relatively low participation in European programmes also owes to their more competitive nature – both for enterprises and researchers – compared with national funds. Although the evaluation dates back to 2010 and Luxembourg's participation in EU programmes has improved since then, considerable room still exists for improvement. In this regard, the government might consider giving FNR a formal role in supporting greater participation of public research organisations in European programmes; similar types of research-funding agencies perform similar roles in many European countries. A joint Luxinnovation-FNR initiative to set up a liaison office in Brussels could be an occasion to further pursue this sort of co-operation.

Besides Horizon2020, Luxembourg participates in a number of European STI organisations. Luxembourg has been a full member of ESA since 2005 and contributes to five additional optional ESA-related programmes. A 2012 evaluation of Luxembourg's participation in ESA programmes highlighted the positive developments and spillovers for Luxembourg's STI system: Luxembourg has been able to valorise existing capabilities in satellite communications and support national players' market positioning in the European space sector. The country has also developed strong linkages with European

countries with strong space research capabilities (i.e. France, Germany and Italy, as well as Belgium and Switzerland), notably in areas related to environmental research and geophysics. However, more limited impacts were found in terms of skill development at the national level and the overall visibility of the space sector in Luxembourg.

Luxembourg also participates in other international science and research organisations, including the European Molecular Biology Laboratory, the European Co-operation in Science and Technology, the European Research Consortium in Informatics and Mathematics and the European Strategy Forum on Research Infrastructure.

Promoting innovation in the Grande Région

The Grande Région is the cross-border region covering the territories of Luxembourg, Wallonia and the German-speaking community of Belgium, the Lorraine region in France and the two German *Länder* of Saar and Rheinland-Pfalz. Socio-economic ties within the Grande Région have been developed since the Middle Ages. In more recent times, some semblance of cross-border governance at the Grande Région level dates back to the early 1970s. Every two years, each of the member jurisdictions holds a temporary role as President of the Grande Région, in a similar fashion to the rotating presidency of the European Union. The main governing body of the Grande Région is the Summit of the Executives of the Grande Région, created in 1995, which gathers the executive heads of the member jurisdictions. The Summit takes place approximately every two years and issues a common declaration articulating strategic orientations for cross-border co-operation.

Successful collaborations in fundamental science depend on finding the most suitable partners, irrespective of their location, and should be based on excellence at the international level. The same criteria should apply when recruiting PhD students, researchers and professors. For other types of activities and collaboration, however – e.g. involving business-development agencies, clusters, SMEs or services that are best delivered by local actors – critical mass, agglomeration and proximity can be decisive. The 2007 OECD Review recommended focusing on the Grande Région for some aspects of STI policy making. It observed that Luxembourg firms are to a large extent oriented towards international markets and that many of them, especially domestic companies, consider the Grande Région as their natural "home market". For these reasons, the Review recommended adapting innovation-policy instruments to serve networks in the Grande Région.

Business-sector actors welcome the opportunities offered by the Grande Région to gain critical mass and increase international visibility. Luxinnovation organises matchmaking events in the Grande Région, e.g. during the Grande Région Business Days and the "Business Meets Research" events bringing together many actors from across the Grande Région. For example, the 2013 edition was co-partnered by the Wallonia region in Belgium. Today, some of the instruments supporting innovation, particularly clusters and incubators, serve actors on both sides of the border:

- In some areas, e.g. the material sciences, cross-border co-operation on innovation and business development is more advanced. The Luxembourg Materials Cluster participates in the Interreg IVa project intermatGR, a cross-border cluster on materials in the Grande Région.

- The Transfert de technologie et innovation en Grande Région project is an international network in the framework of the Interreg IVa Grande Région. Luxinnovation is a member of this network, together with counterparts in France, Germany and Belgium. The project maps skills and clusters in the Grande Région, organises events, helps firms locate technology and innovation partners, and provides advice on cross-border IP rights.
- The Environment Cluster of the Grande Région, which is co-ordinated by several Summit of the Executives working groups, has started to work on water-related issues. The project also aims to promote the integration of cross-border electricity markets and to make the Grande Région a European model for energy efficiency and renewable energies.

As of higher education institutes, developing joint undergraduate study programmes and sharing sophisticated and costly scientific equipment may benefit the smaller actors in the area, such as the University of Luxembourg, which particularly need critical mass. The University of Luxembourg is part of the University of the Grande Région (UniGR), a cross-border university network that could be better exploited to deliver joint undergraduate study programmes (Box 4.14).

Box 4.14. **The University of the Grande Région (UniGR)**

UniGR was initiated thanks to EU Interreg IVa funding (approximately EUR 6 million) in 2008 for a fixed duration of three-and-a-half years. The partnering institutes are the University of Liège (Belgium), the University of Lorraine (France), the University of Luxembourg, the University of Saarland (Germany), the University of Trier (Germany) and the Technical University of Kaiserslautern (Germany). UniGR groups more than 100 000 students and 6 000 academic staff over multiple jurisdictions. The member universities are in some cases very different in terms of size, history, language and cultural background: for instance, the smallest and youngest university of the group, the University of Luxembourg, accounts for more than 6 000 students, compared to 52 000 students in the University of Lorraine.

During the Interreg financing phase, UniGR developed five activity modules, each co-ordinated by a university and supported by the entire network. The five modules were: i) governance and marketing, with the aim of developing an identity for a university confederation; ii) mobility, to reduce administrative and financial barriers to student, researcher and teacher mobility; iii) education, to facilitate cross-border programmes in the Grande Région; iv) research, to develop cross-border research programmes; and v) opening, to create partnerships within and beyond the Grande Région and promote spillovers to the business sector.

According to a 2012 European University Association evaluation report of the UniGR Interreg project, UniGR had been successful in gaining good expertise to deal with administrative challenges (caused by the cumbersome administrative procedures related to the cross-border nature of the agreements), building trust and relationships, and organising successful events. Students involved in the project generally gave positive feedback. UniGR had developed useful inventories of educational programmes and made scientific equipment available within the UniGR network. Finally, UniGR was also starting to take advantage of the international visibility that can derive from the greater critical mass of a cross-border network compared to individual institutes. The evaluation, however, also highlighted that UniGR was not yet central to each institute's strategy, and that the governance and rotating presidency of UniGR could cause fragmentation and was not conductive to strong commitments or tough choices. The evaluation also noted that the network's modular structure is not sustainable in the long-run, as it leads to fragmented responsibilities and silos.

Box 4.14. **The University of the Grande Région (UniGR)** (*continued*)

The evaluation recommended that UniGR become more ambitious, demonstrating clear value-added in terms of socio-economic development of the Grande Région. It also recommended focusing on a selected number of scientific priorities that would produce results relevant to all partners in the Grande Région. It stressed the necessity of adequate funding to ensure sustainability of the project in the long-run. Finally, it highlighted how UniGR mobility at the bachelor's level is not convenient for all universities, though it was beneficial to the University of Luxembourg, given its very small size.

After the closing of the Interreg project, the six partnering universities decided to continue and self-fund UniGR, as well as implement some of the recommendations of the evaluation report. The University of Luxembourg has provisionally allocated EUR 1.1 million to UniGR over 2014-17 (EUR 200 000 in 2014, rising to EUR 300 000 a year in the following years). This is a positive, though modest development. Today, UniGR is governed by the UniGR Council, gathering the presidents and the rectors of the member universities to define the co-operation's strategic objectives; a steering group composed of representatives of the member universities, with an advisory role to the Council and Central Bureau and an operational role as well; the UniGR Central Bureau, in charge of defining the strategic goals of UniGR; the UniGR Correspondents, in charge of the dialogue between the UniGR secretariat and the students, researchers, administrative personnel and professors of the member universities; and the Student Council, providing the point of view of students in UniGR governance. The offices of the Central Bureau are located in Saarbrucken, Germany.

Today, the main objectives of UniGR are to simplify administrative procedures for cross-border students and researchers; grant access to classes, libraries and other student services to UniGr students; provide reduced tariffs for public transport in the region to promote mobility; create more joint-diplomas, joint curricula or mutual recognition of exams and diplomas; foster cross-border workshops and seminars; create researcher networks; share costly and uncommon research material and resources; and establish joint PhD programmes.

Following the recommendations of the European University Association evaluation, the post-Interreg UniGR decided to focus its activities on three thematic areas of particular interest for the region: biomedicine, cross-border studies and material science. These three thematic areas were selected on the basis of the interests and strengths of the member universities. Events and cross-border researcher networks are organised and created for each thematic area. Common projects are submitted to funding agencies in different countries, including the FNR in Luxembourg. In addition, experts and co-ordinators of the selected thematic areas are considering the possibility of promoting the submission of common project proposals in the framework of Horizon2020.

Source: University of the Grande Région website (www.uni-gr.eu).

Notes

1. The 2009 RDI law was originally planned to cease effect in 2014, but has been extended to 2020. A new draft law to update the 2009 law is currently under discussion.

2. The Economy Minister can also apply discretionary capped-aid measures, called "*de minimis*", to enable firms and private research organisations to benefit from public funding if these entities are not eligible for a specific aid scheme defined by the law owing to their size or other criteria. All firms and private research organisations established in Luxembourg are eligible.

3. The Haut Comité pour le soutien, le développement et la promotion de l'industrie (High-Level Committee for the Support, Development and Promotion of Industry) was created in 2013 to promote exchanges between the government and Luxembourg's industrial community. It aims to support existing industries in Luxembourg; promote the creation of new industrial activities; and identify new areas for industrial-sector internationalisation and growth. The Committee has discussed several issues related to innovation and identified several issues requiring policy attention, including the need to define a common valorisation strategy for public research organisations; promote P/PPs for research and innovation; develop industrial activities around the material sciences; and attract talent to Luxembourg.

4. Public stakeholders involved in the biomedical field are now associated within the Personalised Medicine Consortium (PMC), an informal body which co-ordinates activities between groups, encourages information sharing and avoids duplicating activity. The PMC focuses on four main priorities: cancer (lung, breast and colon), Parkinson's disease, type II diabetes and a population cohort. The Consortium is open to any actor of the research and medical community who intends to contribute to these common projects. The administration of the PMC is organised within the IBBL.

5. See www.euraxess.lu.

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