University-Industry Collaboration

NEW EVIDENCE AND POLICY OPTIONS

OECD

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BETTER POLICIES FOR BETTER LIVES

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Foreword

This report presents the main outcomes from the project titled *Assessing the Impacts of the Policy Mix for Knowledge Transfer*, conducted in 2017-18 by the OECD Working Party on Innovation and Technology Policy (TIP). The main goals of the project were to analyse the impacts of public research institutions on innovation performance, as well as to explore the policy instruments and mixes implemented across countries to support science-industry knowledge transfer. The project builds on the expertise of the Working Party in knowledge transfer and public research policy domains, and is the follow-up to a previous project on *Assessing the Impacts of Public Research Systems* (2015-16). This strand of work will continue in 2019-20, with a focus on knowledge co-creation.

New empirical evidence provided in this report is the result of efforts to develop two new databases. The first covers 21 619 public research institutions matched to data on 2.5 million patent applications to the European Patent Office (EPO) in 36 countries (35 OECD countries and China), over the period 1992-2014, and is used to explore the patenting activities of universities and their impacts on local business inventions. The second is a database with indicators on the governance of public research, based on a new survey conducted in 2017-18 across 35 OECD countries. This database was obtained following a three-year process that involved the development of an ontology of the governance of public research policy, as well as data collection and validation by national authorities.

The key contribution of the project, as illustrated in this report, includes the implementation of a novel approach to exploring science-industry knowledge transfer using labour force survey data. Such data are examined to provide new evidence of the contributions of graduates in social sciences to different economic sectors of activity. In addition, the report develops a new framework for analysing policy mixes for knowledge transfer – including a detailed taxonomy of financial, regulatory and soft policy instruments – and a new taxonomy of types of positive and negative interactions among policy instruments.

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Reader's guide

This report presents the main outcomes of the OECD TIP Working Party's *Assessing the Impacts of the Policy Mix for Knowledge Transfer* project (2017-18). The report targets in particular policy makers, and contains the main findings and policy recommendations of the project. The report is a synthesis of different materials produced in the context of the project.

The following highly detailed policy papers form the basis for discussions and conclusions presented in this report:

- *Assessing the impacts of public research institutions on industry inventions* (Borowiecki, El-Mallakh and Paunov, 2019) provides evidence on the trends in patenting of public research institutions, and on the co-location of public research and industry. The evidence builds on a dataset compiled for the purposes of this OECD-TIP project on the location and patenting activities of universities and public research institutes (PRIs) across 35 OECD countries and China for 1992-2014. The policy report also presents evidence of the impacts on local innovation of geographical proximity to universities.
- *What role for social sciences in innovation? Re-assessing how scientific disciplines contribute to different industries* reviews the data sources and associated methodologies available to measure different types of science-industry interaction (Paunov, Planes-Satorra and Moriguchi, 2017). The paper also discusses the available evidence, which is mostly based on case study and patent data, and offers new statistical information from labour force and university graduate surveys. Such data allow exploring the numbers of social science graduates who move into different economic sectors; they thus capture the flow of human capital from university to industry – often considered one of the most important channels of science-industry knowledge transfer.
- *Science-industry knowledge exchange: Mapping policy instruments and their interactions* describes the different types of policy instruments aimed at strengthening science-industry knowledge transfer (Guimón and Paunov, 2019). It also discusses the positive and negative interactions between policy instruments. The paper draws on evidence from the case studies countries produced for the purposes for the purposes of this OECD-TIP project.
- *How is research policy across the OECD organised? Insights from a new policy database* provides a first systematic comparison of the governance of public research policy across 35 OECD countries from 2005 to 2017, using a newly created policy indicator database (https://stip.oecd.org/resgov/). The paper shows that diverse mechanisms of policy action regarding higher education institutions (HEIs) and PRIs are in place across these countries (Borowiecki and Paunov, 2018).

The report also builds on twenty case study contributions to this project. This includes fourteen country policy studies – focusing on new policy initiatives for science-industry knowledge transfer, or a country's overall policy mix – and six studies on European research and technology organisations that provide new insights into institutional spin-off support schemes. The case studies are available here: LINK TO WEBSITE.

The report benefited from discussions with experts from industry, academia and government during four project workshops organised jointly with France Stratégie, France; Massachusetts Institute of Technology – MIT, United States; and the Foundation for Science and Technology – FCT, Portugal. Brochures containing summaries of the workshop discussions are available at the websites of each of the events:

- MIT/OECD: Towards effective science-industry co-creation, Paris, 5 December 2018
- France Stratégie/OECD: Boosting knowledge transfer between science and industry: New models and business practices, Paris, 14 March 2018
- OECD: Semantic analysis for innovation policy, Paris, 12-13 March 2018
- FCT/OECD: Stimulating knowledge transfer: Challenges and policy responses, Lisbon, 7-8 November 2017.

This project has been conducted jointly with the OECD TIP project on *Digital and Open Innovation*, which explores how the digital transformation is changing innovation practices and outcomes, and identifies the innovation policy priorities and adjustments needed to foster innovation for inclusive and sustainable growth in the digital age.

References

Borowiecki, M. and C. Paunov (2018), "How is research policy across the OECD organised? Insights from a new policy database", *OECD Science, Technology and Industry Policy Papers*, No. 55, OECD Publishing, Paris, https://doi.org/10.1787/235c9806-en.

Borowiecki, M., N. El-Mallakh and C. Paunov (2019), "Assessing the impacts of public research institutions on industry inventions", *OECD Science, Technology and Industry Policy Papers*, OECD Publishing, Paris.

Guimon, J. and C. Paunov (2019), "Science-industry knowledge exchange: A mapping of policy instruments and their interactions", *OECD Science, Technology and Industry Policy Papers*, OECD Publishing, Paris.

Paunov, C., S. Planes-Satorra and T. Moriguchi (2017), "What role for social sciences in innovation? Re-assessing how scientific disciplines contribute to different industries", *OECD Science, Technology and Industry Policy Papers*, No. 45, OECD Publishing, Paris, https://doi.org/10.1787/8a306011-en.

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Acronyms and abbreviations

ANVUR	Agenzia Nazionale di Valutazione del Sistema Universitario e della Ricerca (National Agency for the Evaluation of Universities and Research Institutes), Italy
BRIICS	Brazil, Russian Federation, India, Indonesia, China, South Africa
CEA	Commissariat à l'énergie atomique et aux énergies alternatives (French Alternative Energies and Atomic Energy Commission), France
CDG	Christian Doppler Forschungsgesesellschaft (Christian Doppler Research Association), Austria
CDH	Careers of Doctorate Holders, OECD/UNESCO/Eurostat project
CIIE	Committee for Industry, Innovation and Entrepreneurship, OECD
CoLAB	Collaborative laboratories, Portugal
CORDIS	Community Research and Development Information Service, European Commission
CSTP	Committee for Scientific and Technology Policy, OECD
CWTS	Centrum voor Wetenschap en Technologische Studies (Centre for Science and Technology Studies), Leiden University, Netherlands
EPO	European Patent Office
ETER	European Tertiary Register
EU-LFS	European Union Labour Force Survey
FCT	Fundação para a Ciência e a Tecnologia (Foundation for Science and Technology), Portugal
FIEK	Felsőoktatási és Ipari Együttműködési Központ (Centres for Higher Education and Industrial Cooperation), Hungary
GmbH	Gesellschaft mit beschrankter Haftung (Company with limited liability), German
HEIs	Higher education institutions
IBF	Inspiring Business Forum, Spain
ICT	Information and communication technologies
ICURe	Innovation to Commercialisation of University Research, United Kingdom
IP	Intellectual property
IPEDS	Integrated Postsecondary Education Data System
ISCED	International Standard Classification of Education
ISIC	International Standard Industry Classification
IST	Institute of Science and Technology, Austria
JPIs	Joint Programming Initiatives, European Union
JPO	Japanese Patent Office
JSIC	Japanese Standard Industrial Classification
KEINS	Knowledge-based Entrepreneurship: Innovation, Networks and Systems, European Union
LabCom	Laboratoires Communs (Joint Laboratories), France
LFS	Labour force surveys
MEC	Ministry of Education and Culture, Finland
MIT	Massachusetts Institute of Technology, United States
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne (Statistical Classification of Economic Activities in the European Community)
n.e.c.	Not elsewhere classified
NPL	Non-patent literature
OrgReg	Register of Public-Sector Organizations, European Union
PCP	Patent Commercialisation Platform, Korea

PRIs	Public research institutes
PROs	Public research organisations
RJIES	Regime Jurídico da Instituições do Ensino Superior (Juridical Regime of Higher Education Institutions), Portugal
RTOs	Research and technology organisations
SATREPS	Science and Technology Research Partnership for Sustainable Development, Japan
SATTs	Sociétés d'accélération du transfert de technologie (Technology transfer acceleration companies), France
SBIR	Small Business Innovation Research, United States
SIC	Standard Industrial Classification
SOC	Standard Occupational Classification
STEM	Science, technology, engineering, math
STI	Science, technology and innovation
TAC	Technology Access Centres, Canada
TIP	Innovation and Technology Policy (OECD Working Party)
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research), Netherlands
TTOs	Technology transfer offices
TUTL	Tutkimuksesta uutta tietoa ja liiketoimintaa (New knowledge and business from research ideas), Finland
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
USPTO	United States Patent and Trademark Office
VC	Venture capital
VTT	Technical Research Centre of Finland
WHED	World Higher Education Database

Executive summary

The increasing importance of knowledge-based capital, both for competitiveness and to address socio-economic challenges, benefits those countries with strong public research and the ability to effectively use research findings to innovate. It therefore becomes ever more important to understand how public investments in research can generate the greatest impacts on innovation. This report provides fresh evidence regarding those impacts, and explores policy tools implemented across OECD countries to support science-industry knowledge transfer.

What are the impacts of science-industry knowledge transfer on innovation?

Assessing the impact of public research on innovation is a complex task given the variety of channels through which knowledge transfer unfolds (e.g. academic spin-offs, collaborative research, patenting and licensing of university inventions, academic consultancy, networking) and their relative importance across science fields and industry sectors. Additional methodological challenges arise, including accounting for factors shaping knowledge exchange such as the industry context and, most importantly, establishing causality relations. Impacts are also likely to be diverse across different research institutions when it comes to status, mission, research specialisation and quality. More investment in building the right samples of data at micro level and using the best tools are necessary to fully understand knowledge transfer dynamics and their impacts on innovation. A combination of different methods and data sources is necessary for any such assessment.

The report provides new evidence on various formal and informal channels of knowledge exchange, including jointly filed patents of higher education institutions (HEIs) and public research institutes (PRIs) with industry; the impact on local innovation of proximity to HEIs and PRIs; student and researcher start-ups; and graduate mobility in social sciences. The evidence presented shows that HEIs and PRIs increasingly engage in "knowledge co-creation" with industry, as reflected by the growth in jointly filed patent applications. Academic spin-off activities are another way for research to contribute in important ways to innovation, as shown by data for student and researcher start-ups. Graduate mobility in social sciences is another key contributor to innovation, particularly for some disciplines and industry sectors such as information and communication technologies (ICT).

In addition, exploration of the causal implications of public research institutions for innovation, based on the geographic location of HEIs and PRIs, points to a positive impact on local industry patenting.

What policy instruments are implemented to support knowledge transfer?

OECD countries have implemented a variety of financial, regulatory and "soft" instruments to boost knowledge exchange between science and industry. A taxonomy presented in this report offers a comprehensive overview of 21 policy instruments, characterised by their targets, the channels they address, and whether their orientation is supply or demand side. Financial instruments include R&D and innovation grants, tax incentives with a focus on collaboration, and financial support to recruit PhDs or postdoctoral students. Regulatory instruments include intellectual property (IP) rights regime, regulations regarding the creation of spin-offs by researchers, and sabbaticals and mobility schemes for researchers. Soft instruments include awareness building, networking events, and the development of guidelines, standards and codes of conduct.

Emerging policy approaches to knowledge transfer include support for science-industry knowledge co-creation (i.e. the joint creation of knowledge by industry, civil society and research by means of joint labs, joint research projects, etc.); the creation of intermediary organisations that help match supply and demand for new technologies (e.g. R&D centres for science-industry collaboration, business incubators, etc.); the use of new forms of open digital innovation enabled by digital platforms; and the development of new programmes to support spin-offs.

What is the impact of the policy mix and governance mechanisms?

When governments add new policy instruments for knowledge co-creation, digital innovation, and academic spin-offs, the impacts of these instruments depend not only on their own features (which vary across countries) but also on the other policies in place. Different policy instruments may reinforce and complement each other when implemented simultaneously, but could also result in contradictions (if one decreases the effectiveness of others) and excessive complexity (if implementing too many instruments results in confusion for target groups, or increased operational difficulties and administrative costs).

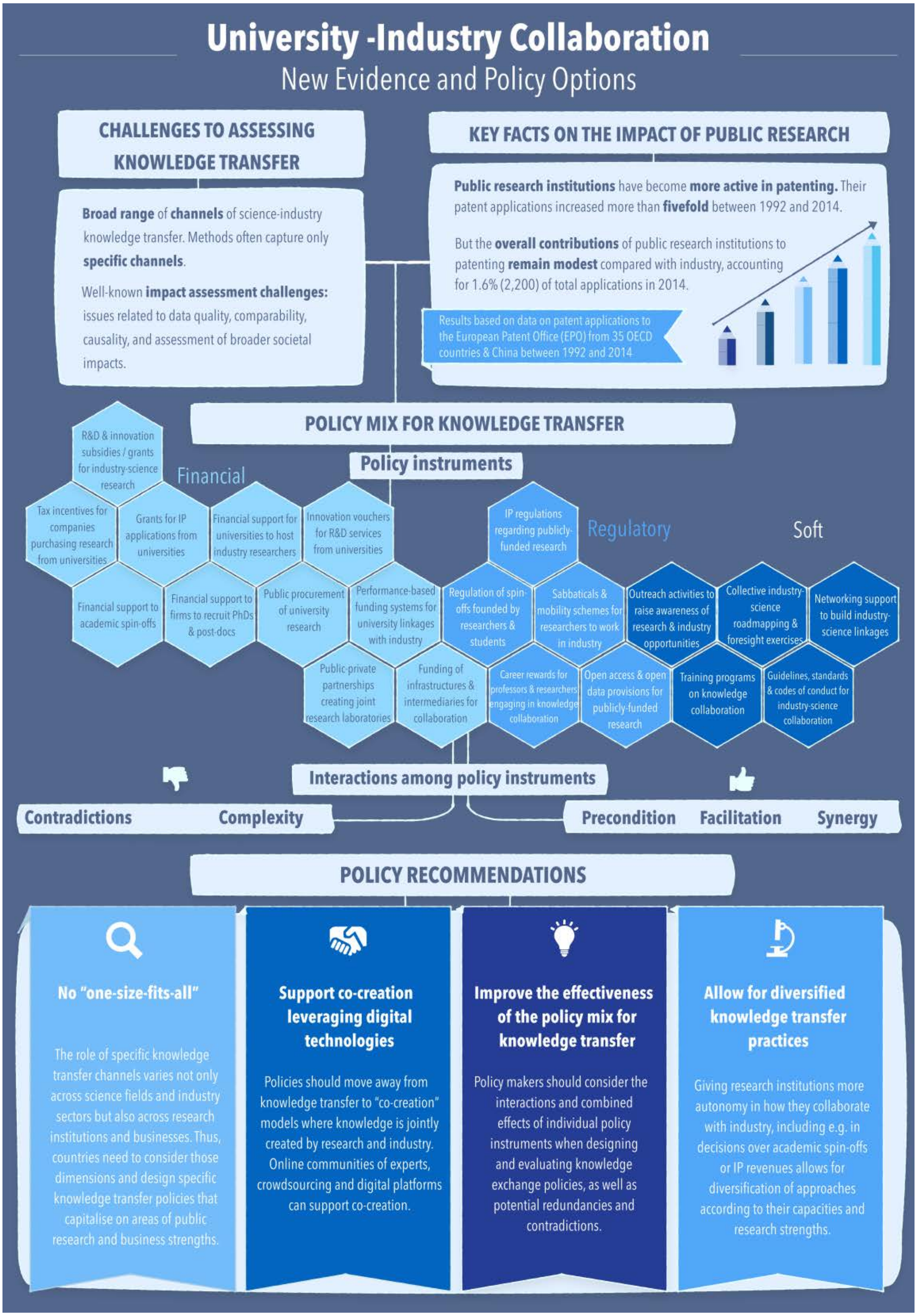
The effectiveness of combining instruments – the policy mix for knowledge transfer – also depends on the governance of public research, which is to say the institutional arrangements that govern policy action regarding publicly funded research in universities and PRIs). The new OECD Database on Governance of Public Research Policy (stip.oecd.org/resgov), built for this project, provides evidence of key governance practices that shape science-industry knowledge transfer. These include the increasing autonomy of universities and PRIs, which allows them to deploy their own support programmes for knowledge transfer; increasing engagement on the part of the business sector and civil society in university boards and research and innovation councils; and the increasing reliance on performance-based funding mechanisms that reward universities and PRIs for their engagement with industry.

Key recommendations

- *Knowledge transfer policies should be tailored and respond to specific industry and research needs*, as the relevance of different knowledge transfer channels varies across countries, science fields and industry sectors, among others.
- *HEIs and PRIs should take advantage of the opportunities for knowledge transfer offered by digital technologies*. New tools such as online communities of experts, open calls and crowdsourcing can be used to facilitate matching supply and demand for innovation.
- *Policy makers should consider interactions among policy instruments when designing and evaluating knowledge transfer policies*, strengthening the synergies and reducing potential redundancies and contradictions. Policy mixes should also be streamlined to avoid confusion for target groups of those policies and reduce implementation costs.

- *National regulations should provide HEIs and PRIs with the autonomy to organise their knowledge exchange activities*, so that these are more targeted to their needs and strengths. Regulatory frameworks should also be revised to facilitate the participation of industry and civil society in governing boards of HEIs and PRIs, and to promote stakeholder consultations in the decision-making processes of these institutions.
- *Policy makers and researchers should exploit the potential of new data sources and methodologies to assess the effectiveness of knowledge transfer policies, such as text mining.* These could be combined with commonly used data sources and methodologies (e.g. patent and publications data).

Synthesis of the report



University -Industry Collaboration

New Evidence and Policy Options

CHALLENGES TO ASSESSING KNOWLEDGE TRANSFER

Broad range of **channels** of science-industry knowledge transfer. Methods often capture only **specific channels**.

Well-known **impact assessment challenges:** issues related to data quality, comparability, causality, and assessment of broader societal impacts.

KEY FACTS ON THE IMPACT OF PUBLIC RESEARCH

Public research institutions have become **more active in patenting.** Their patent applications increased more than **fivefold** between 1992 and 2014.

But the **overall contributions** of public research institutions to patenting **remain modest** compared with industry, accounting for 1.6% (2,200) of total applications in 2014.

Results based on data on patent applications to the European Patent Office (EPO) from 35 OECD countries & China between 1992 and 2014

POLICY MIX FOR KNOWLEDGE TRANSFER

Policy instruments

Financial

- R&D & innovation subsidies / grants for industry-science research
- Tax incentives for companies purchasing research from universities
- Grants for IP applications from universities
- Financial support for universities to host industry researchers
- Innovation vouchers for R&D services from universities
- Financial support to academic spin-offs
- Financial support to firms to recruit PhDs & post-docs
- Public procurement of university research
- Performance-based funding systems for university linkages with industry
- Public-private partnerships creating joint research laboratories
- Funding of infrastructures & intermediaries for collaboration

Regulatory

- IP regulations regarding publicly-funded research
- Regulation of spin-offs founded by researchers & students
- Sabbaticals & mobility schemes for researchers to work in industry
- Career rewards for professors & researchers engaging in knowledge collaboration
- Open access & open data provisions for publicly-funded research

Soft

- Outreach activities to raise awareness of research & industry opportunities
- Collective industry-science roadmapping & foresight exercises
- Networking support to build industry-science linkages
- Training programs on knowledge collaboration
- Guidelines, standards & codes of conduct for industry-science collaboration

Interactions among policy instruments

Contradictions **Complexity**

Precondition **Facilitation** **Synergy**

POLICY RECOMMENDATIONS

No "one-size-fits-all"

The role of specific knowledge transfer channels varies not only across science fields and industry sectors but also across research institutions and businesses. Thus, countries need to consider those dimensions and design specific knowledge transfer policies that capitalise on areas of public research and business strengths.

Support co-creation leveraging digital technologies

Policies should move away from knowledge transfer to "co-creation" models where knowledge is jointly created by research and industry. Online communities of experts, crowdsourcing and digital platforms can support co-creation.

Improve the effectiveness of the policy mix for knowledge transfer

Policy makers should consider the interactions and combined effects of individual policy instruments when designing and evaluating knowledge exchange policies, as well as potential redundancies and contradictions.

Allow for diversified knowledge transfer practices

Giving research institutions more autonomy in how they collaborate with industry, including e.g. in decisions over academic spin-offs or IP revenues allows for diversification of approaches according to their capacities and research strengths.

Main findings and recommendations

Main findings

Challenges in assessing the impacts of science-industry knowledge transfer on innovation and new approaches

Science-industry knowledge transfer unfolds through various formal and informal channels, the relative importance of which varies across science fields and industry sectors. Formal channels include collaborative and contract research, academic consultancy, intellectual property transactions, labour mobility and academic spin-offs. Informal channels of interaction include conferencing and networking, facility sharing, and continuing education provided by universities to enterprises, to name a few.

Given such diverse channels and the differences in knowledge transfer across economic sector and research disciplines, assessing the impact of science-industry knowledge transfer on innovation to reach specific socio-economic objectives is challenging. Other difficulties arise for impact analysis, such as establishing the causal impacts of public research on innovation. Such efforts require gathering representative data to investigate the impact factors of interest, and applying the right analytical tools.

The impacts of science-industry knowledge transfer have typically been assessed using case study evidence, patent data and publications data. Such analyses, however, capture only specific channels, and tend to be biased towards certain disciplines and sectors (e.g. technical innovation in the case of studies based on patent data).

Several new approaches can help improve the evidence on knowledge transfer and its impacts:

Evidence from labour force surveys can help provide a more complete picture of knowledge transfer, given that i) they capture the flow of human capital from university to industry, often considered one of the most important channels of science-industry interaction, and ii) they capture the full spectrum of science fields and industry sectors.

New datasets and tools can also provide fresh insights into knowledge transfer. These include data on innovative start-ups and venture capital deals (e.g. provided by Crunchbase, a commercial database on innovative companies that contains information on their funders and founders). Semantic analysis also provides opportunities for innovation policy analysis, as explored in a recent OECD-TIP workshop (OECD, 2018).

New evidence regarding science-industry knowledge transfer and its impacts

A combination of different methods and data sources is necessary to assess the impact of knowledge transfer. New evidence presented in this report shows that:

- *The direct contributions of universities and PRIs to patenting remain modest, but are growing faster than those of inventions from firms.* Data on patent applications to the European Patent Office (EPO) show that the proportion of those filed by universities and PRIs represented 1.3% of total EPO patent applications over the period 1992-2014. However, the number of patent applications by universities and PRIs increased more than fivefold during that same period, while the number of patent applications of industry doubled.

- *Universities and PRIs increasingly engage in research collaboration with industry.* The number of EPO patent applications jointly filed by public research institutions and industry grew faster than university-owned patent applications. In 2014, the number of co-patent applications with industry made up 43% of all patents applications of universities and PRIs, compared to 24% in 1992.
- *Proximity to universities and PRIs matters for industry inventions.* Data on more than 2.5 million EPO patent applications for 35 OECD countries and China over 1992-2014 show that 50% of all inventive activity by industry occurred within a 30-kilometre distance from a research university. Results from an econometric analysis suggest proximity to universities has a positive significant effect on the growth rate of local industry EPO patent applications is moreover irrespective of local business dynamics or annual time trends.
- *Start-up firms founded by students or academics significantly contribute to commercialising knowledge developed through public research.* Academic start-ups account for around 15% of overall start-up activity. The share of academic start-ups is particularly high in science-based technological fields – for instance, they account for 23% of all innovative start-ups in biotechnology. Start-ups founded by PhD students and academic researchers are significantly more likely to patent than non-academic start-ups.
- *Labour mobility is a key channel of science-industry knowledge transfer, particularly in some disciplines and industry sectors.* New evidence based on labour force surveys provides insights on the contributions of social scientists to industry. Evidence shows that graduates in social sciences (which include economics, political science, sociology, geography, business studies and law) contribute to innovation in a wide range of service sectors, including highly dynamic ICT sectors.

A diversity of policy instruments are used for knowledge transfer

OECD countries use a range of policy instruments to support science-industry knowledge transfer. Examples include grants for collaborative university-industry research; tax incentives for firms that purchase services from universities; mobility schemes for researchers; and networking events. This report identifies 21 specific policy instruments that can be classified according to: i) whether they are financial, regulatory or soft instruments; ii) whether they target primarily firms, universities/PRIs, or individual researchers and research groups; iii) the type of knowledge transfer channels being addressed; and iv) the supply- or demand-side orientation of policy instruments.

While countries tend to use similar sets of policy instruments to support knowledge transfer, differences across countries appear in the relative importance accorded each type of policy instrument (e.g. in terms of budget or number of initiatives), and in the detailed design or implementation of each policy instrument (e.g. in terms of target groups, eligibility criteria, time horizon, monitoring methods, etc.).

The impacts of single instruments depend not only on the features of the instrument but also on other policies in place. Besides the composition of the policy mix, the interactions (both positive and negative) among its elements are critical to outcomes. Synergies reinforce positive outcomes while trade-offs may counteract any positive impacts of policies. This means that a country's choice of financial, regulatory and soft instruments to promote knowledge transfer needs to be coherent so that the different policy instruments reinforce each other rather than result in contradiction, confusion or excessive complexity (Table 1).

Table 1. **Types of interactions between policy instruments**

Type of interaction	Description
Positive interactions	
Precondition	X is necessary in order to implement Y (i.e. the sequence by which policy instruments are introduced matters).
Facilitation	X increases the effectiveness of Y, but Y has no impact on X.
Synergy	X increases the effectiveness of Y, and vice versa.
Negative interactions	
Contradiction	X decreases the effectiveness of Y, and vice versa.
Complexity	Using too many policy instruments results in confusion for target groups, operational difficulties, and increased administrative costs.

Case study evidence illustrates the synergies and trade-offs at play among policy initiatives that support academic spin-offs. Business support – including in the form of marketing or training support – can enhance the effectiveness of financial support measures for spin-offs. In terms of trade-offs, an overly complex set of instruments creates complexity and raises administrative costs, and thus can prove less effective than single policies.

Key trends affecting science-industry knowledge transfer include the following:

- *Creation of new intermediary organisations* – Such organisations include, among others, R&D centres for science-industry collaboration, business incubators, and regional technology transfer organisations. These aim at building bridges between science and industry and differ widely, e.g. in terms of their funding structure, functions and organisational profiles. New approaches include building larger technology transfer offices formed in alliance with several universities and more specialised intermediaries to cater for specific business needs. These TTOs pool services to improve the efficiency and quality of knowledge transfer services with a sectoral or regional focus. Several countries have also developed specific intermediary organisations specializing in the needs of SMEs.

- *Greater emphasis on knowledge co-creation* – Public support for science-industry collaboration is shifting towards more intense "co-creation" relations, which involve the joint creation of knowledge by industry, civil society and research. These may take different forms, such as the creation of joint infrastructures, sharing of resources and engagement in joint research projects. Besides strategic long-term research partnerships and joint labs, co-creation may involve knowledge transfer channels such as the mobility of human capital. This entails building conditions allowing for two-way mobility of researchers from public research institutes and higher education institutions to temporarily join industry, and for industry researchers to temporarily participate in university activities.

- *Adapting knowledge transfer policies to the digital transformation* – New forms of open digital innovation enable more intense collaboration between firms and universities. These include online communities of experts, tournaments, open calls and crowdsourcing. Digital platforms help match supply of and demand for technology by connecting firms with global networks of public research centres, individual scientists and freelancers to solve specific technological problems. In addition, research results and data are becoming more easily (and freely) available through open data and open access practices, while interactions between science and civil society are being enhanced through open science.

Governance mechanisms to promote knowledge transfer

The effectiveness of the policy mix for knowledge transfer depends on the quality of the governance of public research (i.e. the institutional arrangements that govern policy action regarding publicly funded research in universities and PRIs). Instruments will operate differently depending on how universities and PRIs are empowered (or not) in shaping their own ways of reaching the targets set. Interaction among different levels of governance (e.g. national vs. regional) may create synergies but may also lead to duplications and unnecessary complexity in the absence of efficient co-ordination mechanisms. Therefore, when assessing a country's policy mix for knowledge transfer, it becomes critical to analyse the institutions and governance systems that determine how policy instruments are designed and implemented.

The new OECD Database on Governance of Public Research Policy (stip.oecd.org/resgov), built for this TIP project, shows evidence of the following key governance practices that influence science-industry knowledge transfer:

- *Universities and PRIs are autonomous in a large number of OECD countries.* This allows them to deploy their own support programmes for knowledge transfer, on top of those offered across the board by the national or regional governments. In particular, universities and PRIs across many OECD countries can create their own functional units (e.g. technology transfer offices) and legal entities (e.g. spin-offs); decide on the recruitment and promotion of academic staff; and establish the rules that determine the share of IP revenues that researchers may receive.

- *Performance contracts set out the contributions of autonomous universities and PRIs to national innovation objectives as set out in STI strategies*. Performance-based funding systems often include targets related to knowledge transfer, such as collaborative research projects, income from patent licensing, the number of spin-off companies created or income from contract research.

- *The private sector and civil society are participating in shaping how universities engage with industry and are also engaging more actively in policy decision making.* In 25 of 34 OECD countries (or 74%), representatives from industry (e.g. large firms and, increasingly, smaller private firms) are participating in the governing boards of universities. In 26 of 31 OECD countries with research and innovation councils (or 84%), they also participate in policy decision making by participating in research and innovation councils.

Policy recommendations

The following are core policy recommendations for knowledge transfer policies to support innovation and socio-economic development goals:

Set knowledge transfer policies that respond to industry and research needs

- *There is no "one-size-fits-all" policy approach to knowledge transfer.* The importance of specific knowledge transfer channels varies across countries, science fields and industry sectors, and over time with the maturity of science-industry linkages. This means that countries need to consider their economic structures and areas of public research strengths when designing knowledge transfer policies. For example, patenting and academic start-ups are relevant knowledge transfer channels in science-based technological fields (e.g. biotechnology), whereas social scientists contribute to a wide range of service sectors through labour mobility. Consequently, more attention should be placed on adapting the policy mix to the institutional and economic structure of each country.

- *Policies should support public research institutions in developing knowledge transfer activities that are aligned with their research strengths.* Overemphasis on specific channels – often encountered with patenting – may neglect certain strengths, such as the potential to promote student entrepreneurship and academic spinoffs. Patenting and academic start-ups, while very useful for science-based sectors, are concentrated in leading academic institutions, with the leading 100 universities worldwide producing 45% of all academic start-ups. Other institutions may be better at developing student start-ups (which are less science-based) and supporting knowledge transfer through the mobility of students to industry. In the latter case, it is important that academic curricula are regularly revised to respond to emerging industry needs (e.g. strengthening digital skills, setting up more interdisciplinary programmes).

- *Policies should take advantage of opportunities for knowledge transfer offered by digital technologies*. Most innovative approaches to open innovation, enabled by digital technologies, include online communities of experts, open calls and crowdsourcing. Such opportunities can help spur new collaborations and bolster the international competitiveness of the research base.

- *Policies should support strategic, long-term-oriented forms of co-creation.* New policy approaches to promote science-industry links are progressively shifting away from the linear short-term model of knowledge transfer between industry and research in support of economic priorities, and toward a more interactive, longer-term model of knowledge "co-creation" that involves multiple stakeholders from industry, civil society, research and government, and that additionally aims to solve wider societal challenges. Policy initiatives relevant to co-creation include joint research laboratories (e.g. CoLABS in Portugal); the two-way mobility of researchers across organisational boundaries (e.g. through industrial PhDs); the establishment of new intermediary institutions (e.g. Catapult Centres in the United Kingdom); and the development of new guidelines for intellectual property management. The OECD TIP will be launching a 2019-20 project on "Co-creation between industry and science" (DSTI/STP/TIP(2018)16), to explore co-creation and relevant policy approaches.

Strengthen the policy mix for knowledge exchange

- *Countries should increase synergies and reduce complexity in the policy mix for knowledge exchange*. Synergies can be created when different policy instruments complement and mutually reinforce each other. This may be the case with different programmes that support different stages of commercialisation and business support measures, including entrepreneurial training for young start-ups. It is also important to streamline the policy mix, as employing too many policy instruments often results in confusion for target groups, operational difficulties, and increased administrative costs.

- *Policy makers should consider the interactions among policy instruments when designing and evaluating knowledge exchange policies*. Greater efforts are necessary to move towards policy design and evaluation methods that consider the combined effects of policy instruments, as well as potential redundancies, contradictions and remaining problems that could be addressed with new instruments.

- *Giving HEIs and PRIs more autonomy in how they organise knowledge exchange allows for diversification of approaches*, reflecting differences across institutions.

- *New regulatory frameworks should be revised to facilitate the participation of industry and civil society in the governing boards of HEIs and PRIs,* and to promote stakeholder consultations in the decision-making processes of these institutions. Such revision would ensure that the interests and demands of industry and civil society are taken into consideration, including those relating to research directions, teaching curricula, and the local engagement of institutions. This can help make institutions more responsive to business and societal needs.

- *Exploit the potential of new data sources and methodologies to assess knowledge transfer.* Better metrics are necessary to better assess knowledge transfer. This includes combining commonly used data sources and methodologies (e.g. patent and publications data) with new data sources and techniques. For example, text-mining may allow more systematic analysis of the content of scientific publications and patents, revealing the extent to which a publication is truly novel, or whether a patent is related to a particular social concern. (See outcomes of the recent OECD-TIP workshop on semantic analysis for innovation policy in OECD, 2018.) More can also be learned from using more labour force and employer-employee surveys to unveil the contributions of labour mobility to knowledge transfer – often considered the main channel of science-industry interaction.

References

Borowiecki, M. and C. Paunov (2018), “How is research policy across the OECD organised? Insights from a new policy database”, *OECD Science, Technology and Industry Policy Papers*, No. 55, OECD Publishing, Paris, https://doi.org/10.1787/235c9806-en.

Botero Ospina, M., A.E. Sánchez Salazar and J. Pontón Silva (2019), “Technology Transfer in Colombia”, Case study produced for the OECD TIP Knowledge Transfer project.

Herstad, S.J. et al. (2010), “National innovation policy and global open innovation: Exploring balances, tradeoffs and complementarities”, *Science and Public Policy*, Vol. 37, pp. 113-24.

Lanahan, L. and M.P. Feldman (2015), “Multilevel innovation policy mix: A closer look at state policies that augment the federal SBIR program”, *Research Policy*, Vol. 44, pp. 1387-1402.

OECD (2018), “Workshop on semantic analysis for innovation policy – Summary of discussions”, Paris, 12-13 March 2018, www.innovationpolicyplatform.org/semantics (accessed on 04 October 2018).

Part I. Documenting the impacts of public research institutions

Part I, which summarises the main findings of the OECD-TIP project module on impact assessment of public research institutions, consists of three chapters. Chapter 1 provides an overview of the different channels for science-industry knowledge transfer, and discusses the main challenges for assessment. Chapter 2 presents findings of the empirical work to evaluate the effects on innovation and entrepreneurship, introducing new evidence – on research institutions' joint patent activity with industry, student and researcher start-ups, and the impact of proximity to research institutions on local innovation. Chapter 3 explores a new approach to assessing knowledge transfer, using labour force survey data to provide new evidence on the contributions of social science graduates to different industries.

Chapter 1. Assessing the impacts of knowledge transfer on innovation: Channels and challenges

This chapter provides an overview of the different channels of science-industry knowledge transfer, distinguishing the formal ones from the informal. It then presents the methods and data sources that have been used to measure the contributions of public research to innovation, summarising the channels of interaction captured by each approach and outlining the respective advantages and drawbacks of each. The final section discusses the main challenges that arise in assessing the impacts of public research policies on innovation.

Introduction

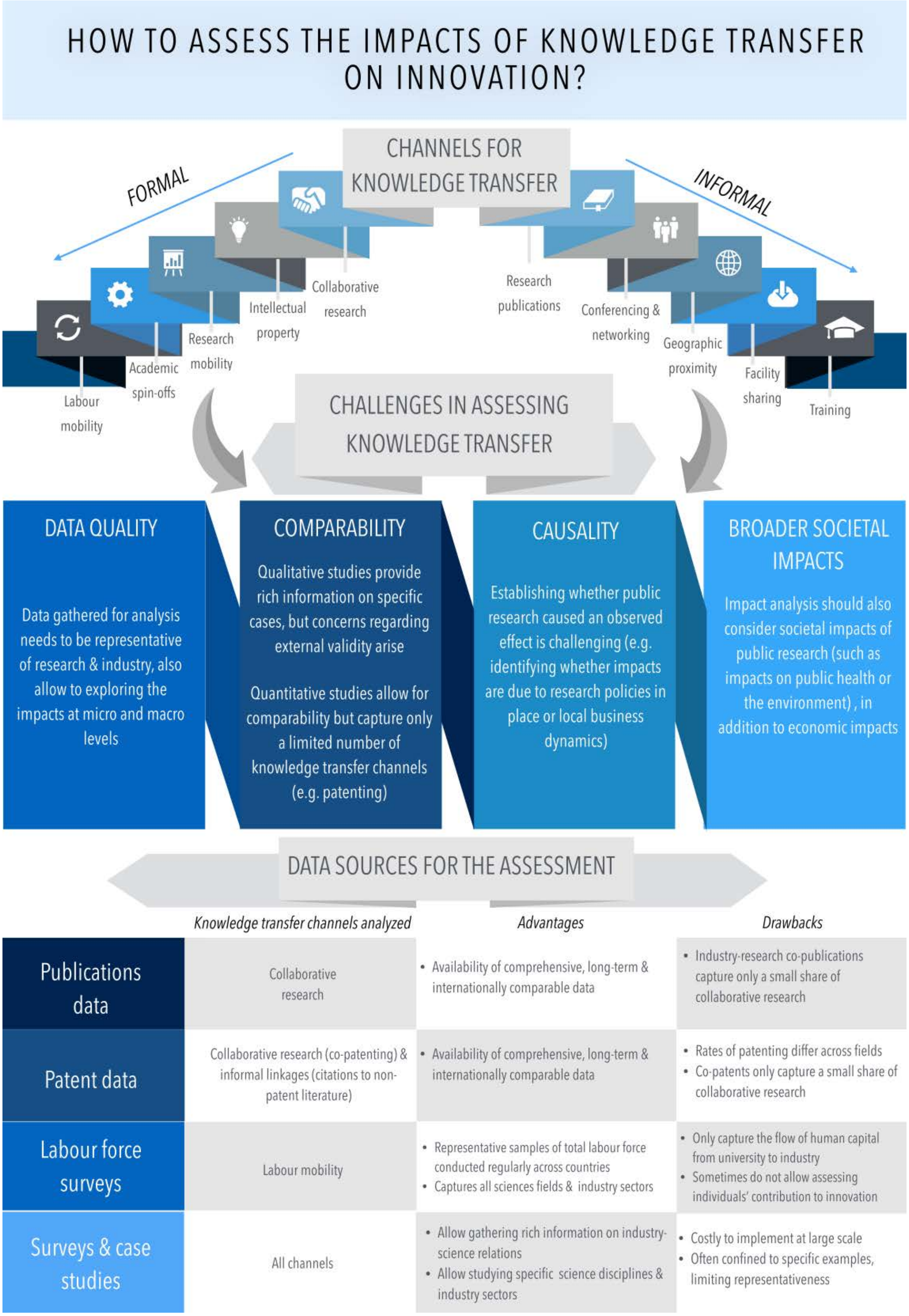
With sizeable public investment in research and mounting budgetary pressures, governments of OECD countries have placed increasing emphasis on enhancing the impact of their investments, specifically concerning their contributions to innovation. Science is a key contributor to building the seeds for innovation and, accordingly, to innovation-driven growth; however, assessing the exact contributions of these investments is a complex process, as the degree of effectiveness is necessarily affected by the efficiency of different knowledge transfer channels in facilitating interactions between industry and science. Accounting for the effectiveness of knowledge transfer is consequently an important but challenging task.

This chapter describes the core channels for knowledge transfer, the methods that have been used to measure impacts, and how these methods perform in tracing the effectiveness of knowledge transfer. The chapter goes on to explain how different methods and sources for measuring knowledge transfer can help shed at least partial light on effective transfer. It also summarises the main challenges in assessing impacts that render effective assessments complex.

The discussion emphasises that this complexity arises from diversity – the very different nature and characteristics of knowledge transfer channels. The limitations of methods to assess this transfer caution against simplistic uses of results. When it comes to assessing impacts, well-known challenges – including causality and limitations to cross-country comparability – need to be taken into account.

The rest of this chapter is structured as follows: Section 1.1 provides an overview of the different channels for science-industry knowledge transfer. Section 1.2 discusses the advantages and disadvantages of the different methods and data sources available to assess the impacts of knowledge transfer. Section 1.3 summarises the main challenges arising for impact assessment. Section 1.4 provides concluding remarks.

Figure 1.1. Synthesis of chapter 1



HOW TO ASSESS THE IMPACTS OF KNOWLEDGE TRANSFER ON INNOVATION?

CHANNELS FOR KNOWLEDGE TRANSFER

CHALLENGES IN ASSESSING KNOWLEDGE TRANSFER

DATA QUALITY

Data gathered for analysis needs to be representative of research & industry, also allow to exploring the impacts at micro and macro levels

COMPARABILITY

Qualitative studies provide rich information on specific cases, but concerns regarding external validity arise

Quantitative studies allow for comparability but capture only a limited number of knowledge transfer channels (e.g. patenting)

CAUSALITY

Establishing whether public research caused an observed effect is challenging (e.g. identifying whether impacts are due to research policies in place or local business dynamics)

BROADER SOCIETAL IMPACTS

Impact analysis should also consider societal impacts of public research (such as impacts on public health or the environment) , in addition to economic impacts

DATA SOURCES FOR THE ASSESSMENT

	Knowledge transfer channels analyzed	*Advantages*	*Drawbacks*
Publications data	Collaborative research	• Availability of comprehensive, long-term & internationally comparable data	• Industry-research co-publications capture only a small share of collaborative research
Patent data	Collaborative research (co-patenting) & informal linkages (citations to non-patent literature)	• Availability of comprehensive, long-term & internationally comparable data	• Rates of patenting differ across fields • Co-patents only capture a small share of collaborative research
Labour force surveys	Labour mobility	• Representative samples of total labour force conducted regularly across countries • Captures all sciences fields & industry sectors	• Only capture the flow of human capital from university to industry • Sometimes do not allow assessing individuals' contribution to innovation
Surveys & case studies	All channels	• Allow gathering rich information on industry-science relations • Allow studying specific science disciplines & industry sectors	• Costly to implement at large scale • Often confined to specific examples, limiting representativeness

1.1. Channels for knowledge transfer

Science-industry knowledge transfer unfolds through various formal and informal channels (OECD, 2013a; Paunov, Planes-Satorra and Moriguchi, 2017). Formal channels of science-industry interaction are:

a) *Collaborative research* – refers to research projects carried out jointly by public researchers and private firms. It can be fully or partly funded by industry, and can range from small-scale projects to strategic partnerships with multiple stakeholders (i.e. public-private partnerships).

b) *Contract research* – refers to research that a private firm commissions universities or PRIs to perform. It generally involves the creation of new knowledge in line with the specifications or goals of the client, and is frequently more applied than collaborative research.

c) *Academic consultancy* – refers to research and advisory services provided by public researchers to industry clients.

d) *Intellectual property (IP) transactions* – refers to the licensing and selling of IP generated by universities and PRIs to industry.

e) *Research mobility* – refers to both university researchers working in industry and the converse, including temporary assignments.

f) *Academic spin-offs* – refers to the entrepreneurial route to commercialising knowledge developed by public research.

g) *Labour mobility* – refers to university graduates that join industry.

Informal channels of interaction that serve the diffusion of knowledge from research to industry and vice versa include the following:

h) *Publication of public research* in scientific journals and other specialised media.

i) *Conferencing and networking* – interaction between public researchers and industry actors can take place in formal conferences or dissemination events, but also in more informal settings (e.g. meetings of former classmates who are employed in public research and industry sectors).

j) *Networking facilitated by geographic proximity* – that is, informal interactions between public research staff and industry researchers. These might be made easy by, for example, locating science parks near university campuses, or firms' laboratories within university campuses.

k) *Facility sharing* between industry and public research (e.g. laboratories, equipment).

l) *Courses and continuing education* provided by universities to enterprises, and lectures at universities held by industry employees.

Activities (a) to (g) involve specific transactions that can be "traced" (such as signed contract agreements, joint industry-science patents and hiring contracts) and even counted (e.g. the number of academic consultancy contracts, IP licences, or researchers hired). Other channels that drive knowledge transfer, as described in (h) to (l), are not always simple to trace. Informal linkages between faculty members and industry, knowledge exchanges in conferences, and specialised media in particular are difficult to measure, but important because they allow transferring tacit knowledge that can be critical to innovation.

The importance of different interaction mechanisms varies across science fields and industry sectors (Schartinger et al., 2002). For example, evidence shows that patenting and licensing are very important for researchers in materials science and chemical engineering, but considerably less so for those in computer sciences (Bekkers and Bodas Freitas, 2008). Contract and collaborative research, labour mobility, and the flow of students from university to industry have been found to be very important in engineering disciplines (Meyer-Kramer and Schmoch, 1998; Schartinger et al., 2002; Balconi and Laboranti, 2006); personal contacts, labour mobility and training courses for firms, meanwhile, have comparatively greater relevance in the social sciences (Bekkers and Bodas Freitas, 2008; Schartinger et al., 2002). Breakthrough academic discoveries in biotechnology are in many cases transferred to industry through university spinoffs (Zucker, Darby and Armstrong, 2002).

1.2. Indicators and methods to assess knowledge transfer

As stated above, measuring the impact of public research on innovation is a complex task given the variety of channels through which knowledge transfer unfolds, but also due to the limitations of available indicators. The relative importance of different channels is hard to measure due to difficulties inherent in impact analysis. For instance, outcomes from basic research translate into highly meaningful contributions to industry, but these are difficult to capture as they may only materialise in the long term. That poses a challenge for assessing the impacts of science-industry knowledge transfer.

Contributions of public research to innovation are typically assessed using the following information sources: i) case studies and specially designed surveys; ii) patent data; iii) publication data; and iv) labour force and university graduate surveys. Table 1.1 summarises the channels of interaction captured by each approach, and outlines the advantages and drawbacks of each.

Table 1.1. **Advantages and drawbacks of different data sources and methods to explore science-industry linkages**

Survey data and case studies	
Channels: All	
Advantages	Drawbacks
• Allow gathering rich specific information about industry-science relations, including on the frequency, direction, nature and impact of linkages • Allow specifying scientific disciplines and industry sectors, helping to establish direct linkages • Allow testing for new science-industry linkage dynamics, as framework is openly defined and allows for multiple ways of obtaining information	• Surveys are costly to implement, especially if intended to obtain internationally representative and comparable data • One-off surveys often yield only limited insights on trends • Case studies are often confined to specific examples or scenarios, which limits their representativeness • Survey design needs to account for subjectivity in reporting of existing relationships • The question of the external validity of findings from often small and not necessarily representative samples of the population studied needs to be assessed

Patent data	
Channels: Collaborative and contract research (co-patenting) and informal linkages (citations to non-patent literature, NPL)	
Advantages	Drawbacks
• Availability of comprehensive, long-term and internationally comparable data allows for cross-country analyses, as well as analyses by organisation, region and technology field (OECD, 2009) • Patent citations to NPL and co-patenting enable contributions of scientific disciplines to be identified and quantified	• Rates of patenting across science fields and industry sectors differ, biasing results • Patents are classified by technology and need an additional connection with industry to identify science-industry linkages • Citations to NPL are a "noisy signal" of knowledge flows: few patents cite NPL; citations are frequently given by examiners or by patent attorneys and do not necessarily reflect inputs used by inventors • Citations to NPL do not capture information on the reverse relationship, i.e. contributions of industry to scientific sectors • Co-patents only capture the small share of collaborative research that results in patenting
Publications data	
Channels: Collaborative and contract research (co-publications)	
Advantages	Drawbacks
• Availability of comprehensive, long-term and internationally comparable publications data allows for cross-country analyses, as well as analyses by university, region and scientific field • Number of co-publications allows quantifying outcomes of joint research activities beyond those resulting in patents	• Industry-research co-publications capture only research collaboration that takes the form of peer-reviewed literature; excluded are reports, policy reports, books and other informal collaborations, disadvantaging certain sciences that rely less on co-publications • Publications may be biased towards collaborative "basic" research, while under-representing collaborations that are more applied in nature and do not result in publications • Bias towards publications authored in English disadvantages more locally oriented research • Industry publications represent a very small share of total publications
Labour force and university graduate survey data	
Channels: Labour mobility	
Advantages	Drawbacks
• Labour force surveys (LFS) are representative samples of the total labour force and are conducted regularly across most countries • University graduate (cohort) surveys are representative samples of the population that graduated in a specific year • Allow capturing the contributions of all sciences, including social sciences, to industry innovation	• Do not capture specific channels of science-industry interaction relevant to innovation other than the flow of skilled human capital from university to industry • Not all surveys collect detailed information on particular academic fields of study or sectors of activity • Surveys are generally not comparable across countries, as academic fields of study and industry classifications used differ • Data do not always allow assessing whether human capital contributes to innovation or to other activities, particularly when the level of academic attainment (i.e. bachelor's, master's or doctoral degree) is not specified

Source: Paunov, Planes-Satorra and Moriguchi, 2017.

Traditional data sources and methodologies to assess science-industry linkages capture only a number of specific channels of interaction, and tend to be biased towards certain disciplines and sectors. In particular, informal channels of interaction remain largely uncaptured, as well as service sectors and social sciences disciplines. Moreover, data on other channels of interaction, such as university spin-offs and academic consultancy, are not collected systematically (except in rare cases), and so only partial information can be obtained. These challenges could be overcome through the development of new indicators and databases, along the lines shown in Box 1.1.

1.3. Main challenges arising for impact assessment

A number of additional challenges to tracing knowledge transfer arise when it comes to assessing the impact of public research on innovation. The CSTP project *Assessing the Impact of State Interventions in Research – Techniques, Issues, and Solutions* pointed to the following important challenges.

(1) Comparability

Qualitative case studies and surveys use tailored questions and methodologies; these allow the analyst to gather rich information on diverse channels of knowledge transfer, including informal channels such as networking and hiring of students. However, qualitative studies – though useful – remain valid only for individual cases, which limits their comparability across cases and countries.

Quantitative studies, on the other hand, are comparable across cases but suffer from limits to the number of impact channels they can trace. The data availability means that formal impact channels, such as patenting and citations of university research, are in focus while others are not.

(2) Causality

The central challenge to any impact analysis is to establish that it is the factor of interest – in this case, public research – that caused the observed effect. In some impact analyses, it is possible to establish causality by estimating the counterfactual situation using a control group (sometimes referred to as a “non-treatment” group). Another approach consists of comparing the behaviour of those being analysed before and after the policy intervention (called ”difference-in-difference” estimation). While these concepts are simple in theory, they are both very difficult to capture in practice and difficult to apply to the case of public research. For this reason, the impact analysis conducted as part of the TIP project discussed in Chapter 2 uses an alternative method, building on an instrumental-variable estimation approach.

A related issue is endogeneity, which refers to a situation where there is feedback from the dependent to the independent variable (called “endogeneity”). An example is identification of the geographic proximity of research institutions to local firms, and the effect on the latter’s innovation performance and growth. Rather than the presence of research institutions, unobserved local business dynamics such as the presence of leading innovative companies may drive performance.

(3) Collection of micro data and samples

Sampling for impact analysis needs to take into account the distribution of activities and impacts at the micro level. There is agreement in literature that research activity is concentrated among a handful of leading firms and top scientists; the great bulk of top research is produced by a small minority of researchers. In innovation, it is equally well understood that only a very small minority of R&D projects are likely to enjoy commercial success. A random sample of beneficiaries of policy support instruments can easily miss the few projects that lead to commercial success, leading the evaluator to misjudge the performance of the policy instrument.

An assessment of science-industry knowledge transfer should also account for characteristics of researchers, research institutions, and industry. Leading research teams that produce excellent research may attract more industry funding, while R&D active enterprises are in a better position to apply university research. A related question is how industry and regional characteristics, such as the presence of R&D-intensive industry, clusters of high-tech start-ups, affect science-industry interactions. Better data on the properties of individual researchers, research institutions, and enterprises are key to understanding drivers of knowledge transfer.

(4) Consideration of broader societal impacts

A number of desirable outcomes beyond immediate economic benefits have been neglected in impact analysis, including improved professional skills as a result of policy support instruments aimed at boosting innovation performance. There is also a need for better analysis of the role of students in research impacts, as opposed to education impacts. Moreover, the contributions of public research in addressing societal challenges are not as yet well understood. For instance, decades of investment in public research are at the basis of current developments in the field of AI, a number of which are specifically targeted at tackling social and environmental challenges, such as using AI techniques to improve medical diagnoses, identify illegal fish vessels or optimising food distribution networks in areas facing shortages (Chui et al, 2018).

Box 1.1. **Overcoming challenges to better assess science-industry linkages**

To complement traditional indicators analysed in Table 1.1, use could be made of other data sources that could shed additional light on science-industry linkages. These are the following:

- Data on university-industry contracts, which could allow systematic tracking to establish which industries connect with which academic disciplines.
- Information on publicly funded science-industry collaborative research projects. For example, the European Commission's Community Research and Development Information Service (CORDIS) gathers information about all Horizon 2020 projects. Linkages could be explored by collecting and analysing science and economic data from the academic and industrial partners involved in each project.
- Information on university spin-off activities, which would help identify which science fields generate research for commercialisation. Several countries – including Australia, Finland, France, Korea, the United Kingdom and the United States – have collected such information, frequently at the institutional level. However, such data are often not (as yet) systematically consolidated across institutions, hampering national and cross-country analyses.
- Information from science clusters. While clusters can generate potentially rich information, using it to systematically uncover science-industry relations at the national level may be challenging because of the highly specific contexts of regional clusters.
- Surveys to track labour mobility patterns of doctorate holders, with specific information on academic background and industry field of work, such as the OECD/UNESCO/Eurostat project on the careers and mobility of doctorate holders.
- Surveys to track the labour mobility of professionals in specific science fields, gathered for example by professional associations at the national and international levels.
- Data obtained through web scraping (i.e. the process of automatically extracting information from websites). This technique may offer interesting opportunities for future analyses – for example, if it is implemented to gather systematic information on the skills sought by different industry sectors based on the information contained in their online job offers. The LinkedIn and Monster databases, among others, may offer opportunities in this regard.
- Data obtained through the use of text-mining techniques, often following prior identification of keywords by expert groups. Portugal has experimented with this approach in assessing its research base in strategic priority sectors

Source: Paunov, Planes-Satorra and Moriguchi, 2017.

1.4. Conclusions

Many different methods and data sources are used to measure knowledge transfer, which reflects the complex nature of science-industry interactions and their multidimensional impacts on innovation. The appropriateness of specific data sources and methodologies depends on the objectives of the assessment as well as on the characteristics of the science fields and industry sectors analysed. A multi-method approach combining different data sources and methods will be necessary when the objective is to assess the overall impacts of public research on industry innovation. Another challenge of impact assessment is the comparability of results across countries and industries, and the identification of causal impacts. Results from impact assessment using single methods – including the cross-country exercises described in this report – shed light on specific aspects but not all dimensions of knowledge transfers. Efforts aimed at using new data with the right tools, such as semantic analysis as discussed at the CSTP-TIP workshop *Semantic Analysis for Innovation Policy*, will help improve the knowledge base.

References

Balconi, M. and A. Laboranti (2006), "University-industry interactions in applied research: The case of microelectronics", *Research Policy*, Vol. 35, pp. 1616-1630.

Bekkers, R. and I.M. Bodas Freitas (2008), "Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter?", *Research Policy*, Elsevier, Vol. 37, pp. 1837-1853.

Chui, M., M. Harryson, J. Manyika, R. Roberts, R. Chung, A. van Heteren, P. Nel (2018) *Notes from the AI frontier: Applying AI for social good,* McKinsey Global Institute, Discussion Paper December 2018.

Meyer-Krahmer, F. and U. Schmoch (1998), "Science-based technologies: University-industry interactions in four fields", *Research Policy*, Vol. 27, pp. 835-851.

OECD (2013), *Commercialising Public Research: New Trends and Strategies,* OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264193321-en.

OECD (2009), OECD Patent Statistics Manual, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264056442-en.

Paunov, C., S. Planes-Satorra and T. Moriguchi (2017), "What role for social sciences in innovation? Re-assessing how scientific disciplines contribute to different industries", *OECD Science, Technology and Industry Policy Papers*, No. 45, OECD Publishing, Paris, https://doi.org/10.1787/8a306011-en.

Schartinger, D. et al. (2002), "Knowledge interactions between universities and industry in Austria: Sectoral patterns and determinants", *Research Policy*, Vol. 31, pp. 303-328.

Zucker, L.G., M.R. Darby and J.S. Armstrong (2002), "Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology", *Management Science*, Vol. 1, pp. 138-153.

Chapter 2. How does public research affect industry innovation and entrepreneurship? New evidence

This chapter explores the direct contribution of public research to technical inventions, based on a newly compiled database covering 36 countries over the period 1992-2013 that matches data on public research institutions and patent applications to the European Patent Office. Based on this data, it looks at technology trends in university patenting; trends in university-industry research collaboration (based on joint patenting activity); differences in the characteristics of public research patents and private patents; and the impact of public research institutions on local innovation (i.e. the importance of geographic proximity). The last section explores the characteristics of academic start-ups based on data from Crunchbase for OECD and BRICS countries for the period 2001-16. It presents trends observed with three types of academic start-ups: companies with a student founder, a PhD founder, and a founder with research experience.

Introduction

Assessment of the impacts of universities and public research institutions (PRIs) on commercial innovations and innovative entrepreneurship is at the top of the policy agenda, due to increasing demands for effective public investment. There is agreement that public research (which refers to universities and PRIs unless otherwise indicated) contributes to innovation and entrepreneurship via different channels of knowledge transfer, including university inventions, academic start-ups, and informal science-industry linkages, all of which are facilitated by the proximity of universities and firms.

Several statistical analyses have investigated impacts of universities on productivity and innovation, generally using data for a single country. Research has shown that the establishment of a new technical university increased the number of industry patents in Finland over the period 1988 to 1996 (Toivanen and Väänänen, 2016). Andersson, Quigley, and Wilhelmsson (2009) use Swedish firm, university and patent data to show that increases in the number of university researchers had a positive impact on regional labour productivity in Sweden between 1985 and 2001. For the United States, Kantor and Whalley (2014) use US university survey data for the years 1981 to 1996 to show that research universities exhibited positive effects on the local economy. However, to date little cross-country evidence exists to document the contributions of higher education institutions (HEIs) and PRIs to inventions, start-ups, and research institutions' contributions to local innovation and entrepreneurship.

This chapter provides fresh evidence on the patenting activities of universities and their impacts on local business inventions. It also discusses evidence on academic start-ups as identified in Crunchbase. Crunchbase is a commercial database of start-ups and it is increasingly used by the venture capital industry as a "the premier data asset on the tech/startup world".[1] It contains information on companies, their founders and funding events such as Venture Capital deals, initial public offerings (IPOs) and acquisitions. Dalle, den Besten, and Menon (2017) present a detailed discussion of the database and its potential for economic, managerial, and policy-oriented research. The sample used for this chapter contains 40 363 start-ups. These firms are matched to HEIs and PRIs using information on the founders' educational history. The database covers OECD and BRICS countries for the period 2001-16.

The following main findings emerge from these analyses:

- Universities and PRIs themselves have become more active in patenting over the past two decades: the number of European Patent Office (EPO) patent applications of research institutions increased more than fivefold in the period 1992-2014.
- Some of the patenting activity of universities and PRIs takes place in collaboration with industry. EPO patent applications jointly filed by public research institutions and industry – reflecting knowledge co-creation between science and industry– grew faster than university-owned patent applications.
- Data on more than 2.5 million EPO patent applications for 35 OECD countries and China over 1992-2014 show that 50% of all inventive activity by industry occurred within a 30-kilometre distance from a research university. Results from an econometric analysis suggest proximity to universities has a positive significant effect on the growth rate of local industry EPO patent applications is moreover irrespective of local business dynamics or annual time trends.

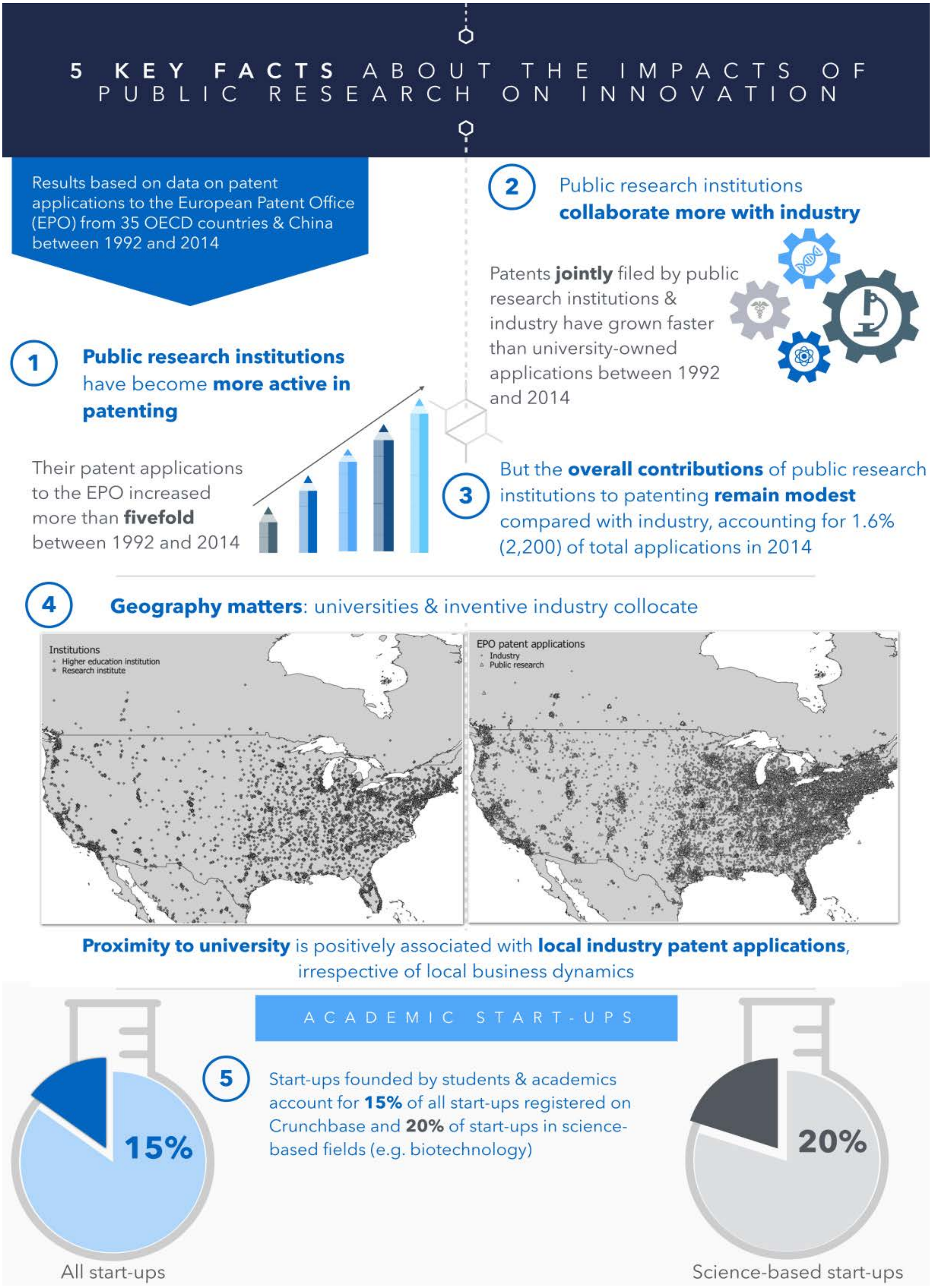
- Academic start-ups – defined as start-ups established by students, PhDs and researchers – account for around 14-15% of overall start-up activity registered on Crunchbase between 2001 and 2016. The share of academic start-ups is particularly high in science-based technological fields, for example accounting for 23% of all innovative start-ups in biotechnology. These start-ups are more innovative than others in that start-ups founded by PhD students and academic researchers are significantly more likely to patent than non-academic start-ups.

The findings presented in this chapter have a number of limitations (see Annex 2.A1). Cross-country assessment of academic technical inventions and academic start-ups, however useful, sheds light only on selected channels of knowledge transfer. The data used are somewhat limited, especially those for smaller HEIs and PRIs. The data on start-ups are based on activity recorded on Crunchbase, which provides a snapshot of entrepreneurial activity but which itself has limitations compared to census information (see Dalle, den Besten and Menon, 2017). Crunchbase also lacks information on start-ups that failed and ceased operations.

The chapter is based on TIP work to assess the impact of public research institutions on industry inventions (Borowiecki and Paunov, 2018). It also draws from a policy report conducted for the Committee for Industry, Innovation and Entrepreneurship (Breschi et al., 2019) that provides evidence on the linkages between public research institutions and innovative entrepreneurship, focusing on start-ups created by founders who are undergraduate students, doctoral students, or academic researchers.

The remainder of the chapter is structured as follows. Section 2.1 describes the contributions of research institutions to patented inventions. Section 2.2 analyses whether proximity to public research matters for industry inventions. Section 2.3 focuses on academic entrepreneurship. Section 2.4 concludes.

Figure 2.1. Synthesis of chapter 2



5 KEY FACTS ABOUT THE IMPACTS OF PUBLIC RESEARCH ON INNOVATION

Results based on data on patent applications to the European Patent Office (EPO) from 35 OECD countries & China between 1992 and 2014

1 **Public research institutions** have become **more active in patenting**

Their patent applications to the EPO increased more than **fivefold** between 1992 and 2014

2 Public research institutions **collaborate more with industry**

Patents **jointly** filed by public research institutions & industry have grown faster than university-owned applications between 1992 and 2014

3 But the **overall contributions** of public research institutions to patenting **remain modest** compared with industry, accounting for 1.6% (2,200) of total applications in 2014

4 **Geography matters**: universities & inventive industry collocate

Proximity to university is positively associated with **local industry patent applications**, irrespective of local business dynamics

ACADEMIC START-UPS

5 Start-ups founded by students & academics account for **15%** of all start-ups registered on Crunchbase and **20%** of start-ups in science-based fields (e.g. biotechnology)

2.1. The contribution of public research to technical invention

One way for higher education institutions and public research institutes to inform innovation is by filing patent applications, introducing in this way state-of-the-art knowledge for commercial application. HEI and PRI inventions are those created by inventors based in HEIs or PRIs. Patents can be filed by an institution seeking protection for an invention made by one of its researchers, by researchers filing directly or, in the case of collaborations, firms. Studies show that in a number of countries – e.g. Denmark (Lissoni et al., 2009) and France (Della Malva, Lissoni and Llerena, 2013) – researcher-held patents account for the majority of all university patents, while they account for one-third of university patents in the United States (Aldridge and Audretsch, 2010).

This section provides results on patents filed by universities/PRIs and industry on the basis of a new dataset compiled by the OECD. The dataset describes the patenting activity of 20 583 universities and 1 036 PRIs for 35 OECD countries and China for 1992-2014, as captured by 32 807 patent applications to the EPO. The dataset also measures the inventive activity of industry captured by more than 2.5 million EPO patent applications. Development of the database involved i) building a census of all universities and leading PRIs for the 36 countries included in the study, ii) matching EPO patent applications from the EPO Worldwide Statistical Patent Database (PATSTAT) to universities and PRIs, and iii) postal code-level mapping of universities and PRIs and of EPO patent applications for 1992-2014. The Annex to this chapter provides further information about the data.

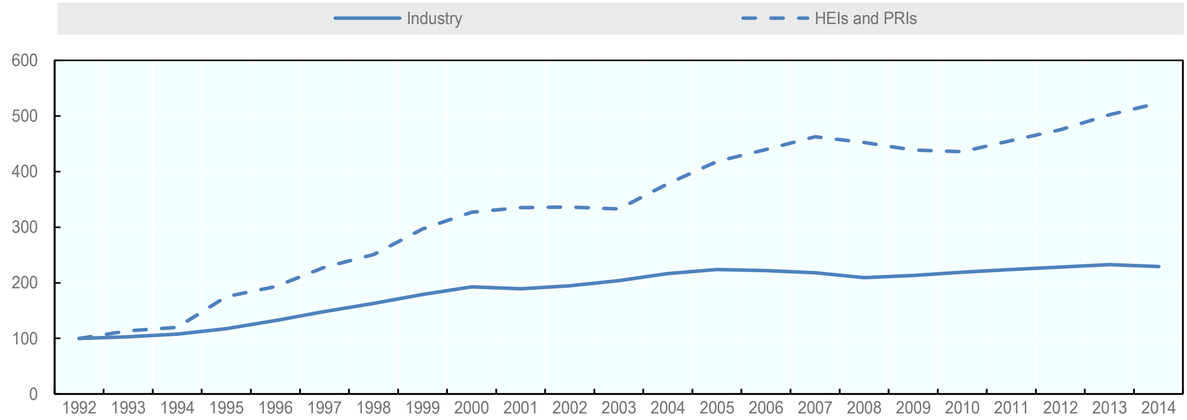
Trends in the numbers of patent applications from universities and PRIs

The findings show that the direct contributions of universities and PRIs to patenting remain modest compared with industry, but are growing faster than patents from firms. In particular, the proportion of patent applications filed by universities and PRIs accounted for 1.3% of total patent applications at the EPO over the period 1992-2014.

Looking at the trends, in 1992-2014 the number of EPO patent applications of research institution increased more than fivefold (Figure 2.2). This corresponds to a total of around 32 807 EPO patent applications. The share of EPO patent applications of universities and PRIs in total EPO patent applications increased from 0.7% in 1992 to 1.6% in 2014.

Figure 2.2. **Trends in number of EPO patent application**

1992 = 100



Source: OECD calculations based on the EPO Worldwide Statistical Patent Database (PATSTAT) (2018).

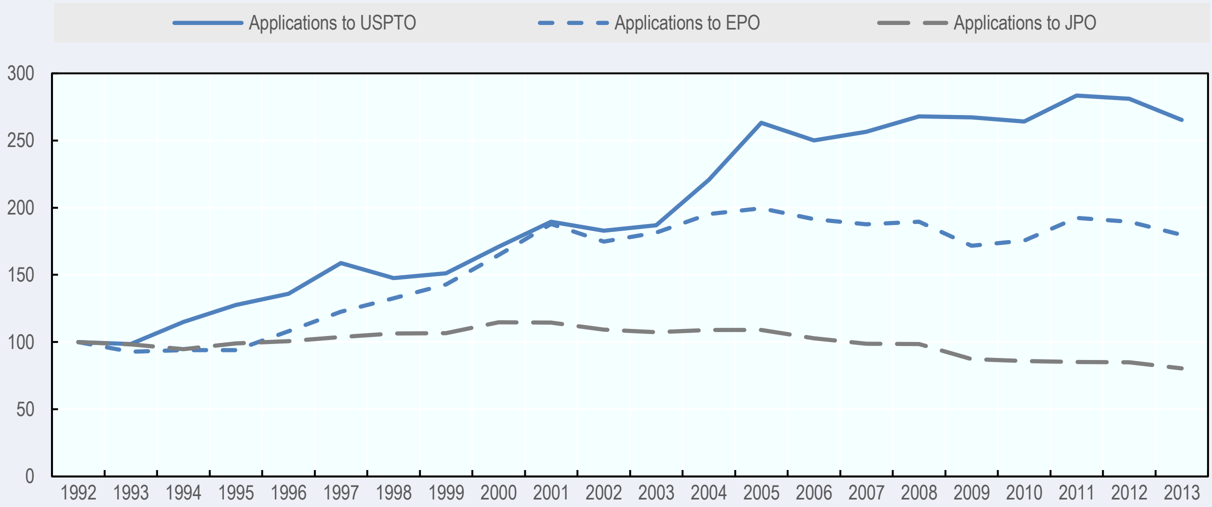
Box 2.1. **Trends in Japanese public sector patent applications**

Data for 1992-2013 show that a large share of Japanese patent applications in the European Patent Office (EPO) are filed by private firms, while those filed by public research institutions and joint public-private applications remain marginal. Nonetheless, while applications to the Japanese Patent Office (JPO) decreased over that period, applications to the United States Patent and Trademark Office (USPTO) and EPO increased steadily, as shown in Figure 2.3, suggesting that there has been a trend towards greater internationalisation of patent applications.

While private sector applications continue to account for a larger share of total Japanese applications to EPO, there has been a sharp increase in the number of applications from public sector (i.e. HEIs and PRIs) as well as of joint applications from private and public sectors since 2000 (see Figure 2.6). Patent applications jointly filed by universities or PRIs and industry reflect increased science-industry research collaborations.

Figure 2.3. **Trend in Japanese patent applications, by patent office**

1992 = 100



Source: Fujishiro, R., "The patenting behaviour of Japanese public sector patent applicants", unpublished mimeo. OECD calculations based on the EPO Worldwide Statistical Patent Database (PATSTAT) (2018).

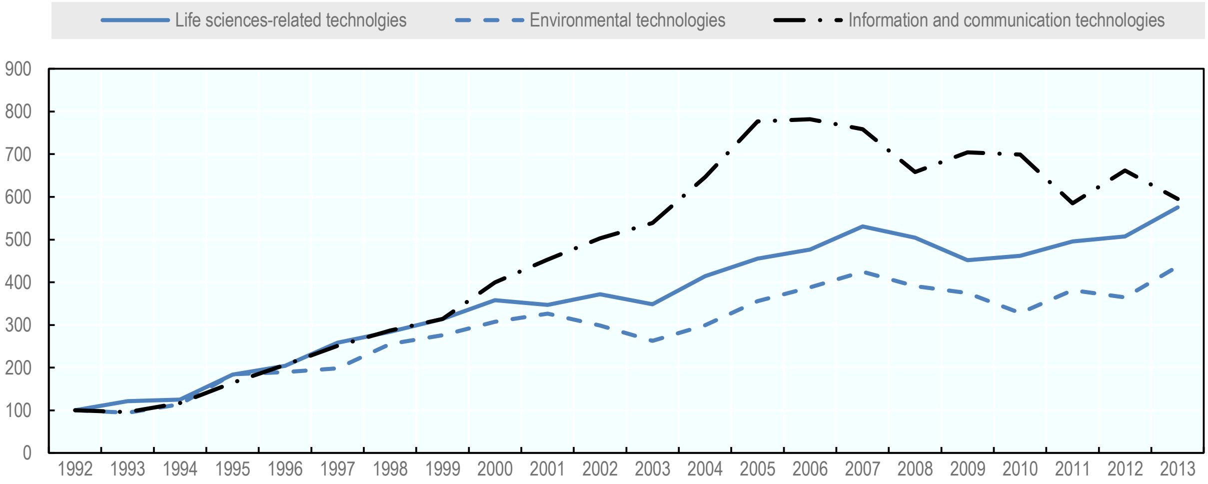
In which technologies are university patents increasing?

HEIs and PRIs mostly engage in life science-related technologies (i.e. biotechnology), information and communication technologies (ICT), and environmental technologies, including $C0_2$ storage, electric vehicles, renewable energy, and water and waste treatment. Between 1992 and 2013, 48% of all EPO patent applications of HEIs and PRIs were filed in life science-related technologies, while 16% of HEI and PRI patents involved ICT, and 13% environmental-related technologies. This confirms existing evidence that research produced in these fields is more tangible and easier to codify, leading to more opportunities for HEIs and PRIs to patent and license their inventions. Regarding the contributions HEI and PRI technologies to overall numbers of EPO patents, HEIs and PRIs produced 4% of all patent applications in life sciences, 1% in ICT, and 1% in environmental technologies.

The evolution of the research and higher education institutions' patenting points to different technological trajectories between 1992 and 2014 (Figure 2.4). The data show that the number of these institutions' patent applications in ICT peaked around 2007, after which the numbers decreased. This is not to say that ICT patents are not important for HEIs and PRIs: they represented 11% of their collective patented inventions in 2013. For life sciences, the EPO patent applications of HEIs and PRIs have increased considerably since 1992, contributing 5% of overall EPO patent activity in this field in 2013. Similarly, the number of EPO patent applications in environmental technologies has risen continuously since 1992, albeit from initially low levels. This increase was largely driven by technologies for air pollution abatement and water-related adaptation technologies such as those for conservation, distribution and storage.

Figure 2.4. **Trends in the number of EPO patent application in selected technologies**

1992 = 100



Note: Environmental technologies include those for waste treatment; conservation, irrigation, distribution, and storage of water; renewable energy; enabling technologies (i.e. energy storage, batteries, thermal storage, fuel cells, and smart grids); CO_2 capture and storage technologies; and transportation technologies (e.g. electric vehicles, hybrid vehicles). ICT includes telecommunications, computers, and office machinery. Life sciences include biotechnology, pharmaceutical technologies, and medical instruments.
Source: OECD calculations based on the EPO Worldwide Statistical Patent Database (PATSTAT) (2018).

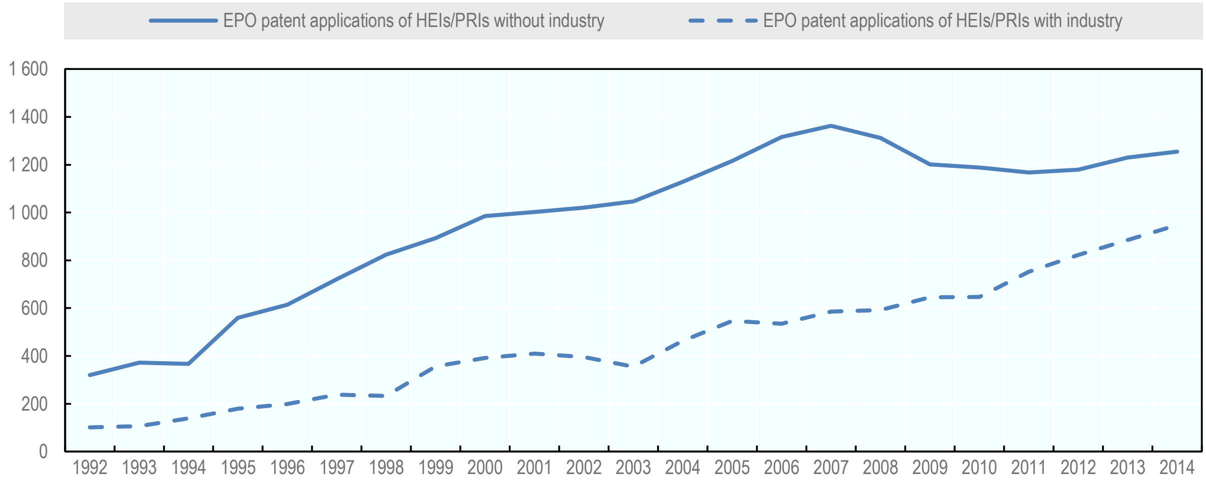
Is university-industry research collaboration increasing?

Patent applications jointly filed by universities or PRIs and industry are a typical indicator of science-industry research collaborations. Figure 2.5 shows that science-industry co-applications grew faster than single patent applications by universities and PRIs. In 2014, the number of co-applications with industry stood at around 948, or 43% of all EPO patent applications of universities and PRIs, up from 24% in 1992.

In the particular case of Japanese patent applications to the EPO, data show that there has been a sharp increase in the number of applications from the public sector (HEIs and PRIs) as well as that of joint applications from private and public sectors since 2000 (Figure 2.6).

Figure 2.5. **Number of EPO applications of universities and PRIs with and without industry**

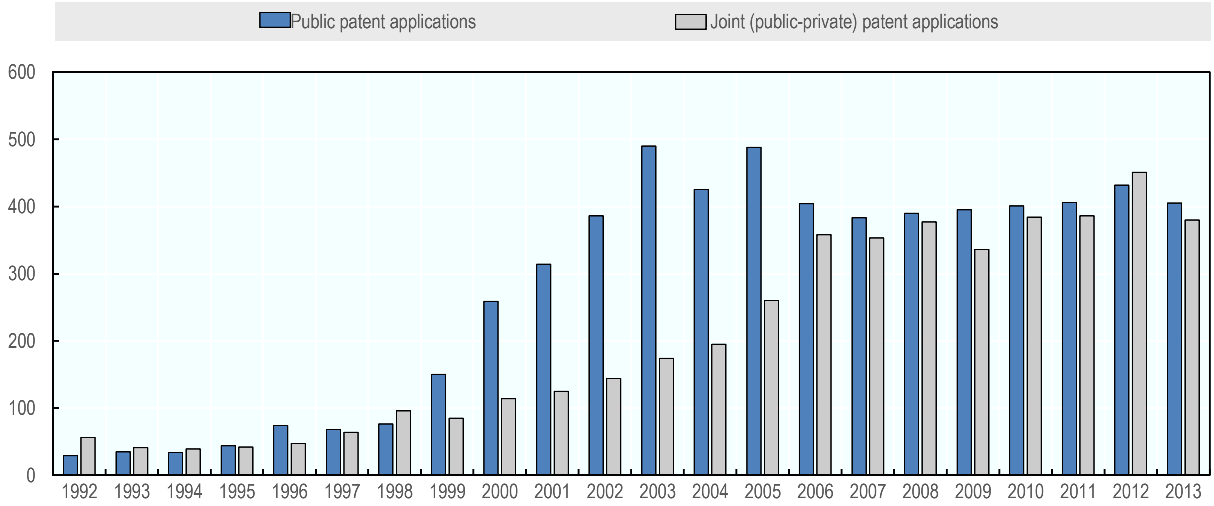
1992-2014



Source: OECD calculations based on the EPO Worldwide Statistical Patent Database (PATSTAT) (2018).

Figure 2.6. **Numbers of public and public-private Japanese patent applications to the EPO**

1992 - 2013



Note: Public refers to research of higher education institutions (HEIs) and public research institutes (PRIs).
Source: Fujishiro, R., “The patenting behaviour of Japanese public sector patent applicants”, unpublished mimeo. OECD calculations based on the EPO Worldwide Statistical Patent Database (PATSTAT) (2018).

Is public research different from private research?

Scientific and technological knowledge has varying characteristics, making it far from homogeneous. Yet generally speaking, universities and other public research organisations may be better suited to advance knowledge in research areas that are critical but that private firms are not capable of working on, or that lack the incentive. Characteristics that may differentiate public inventions from that of their private counterparts are the following:

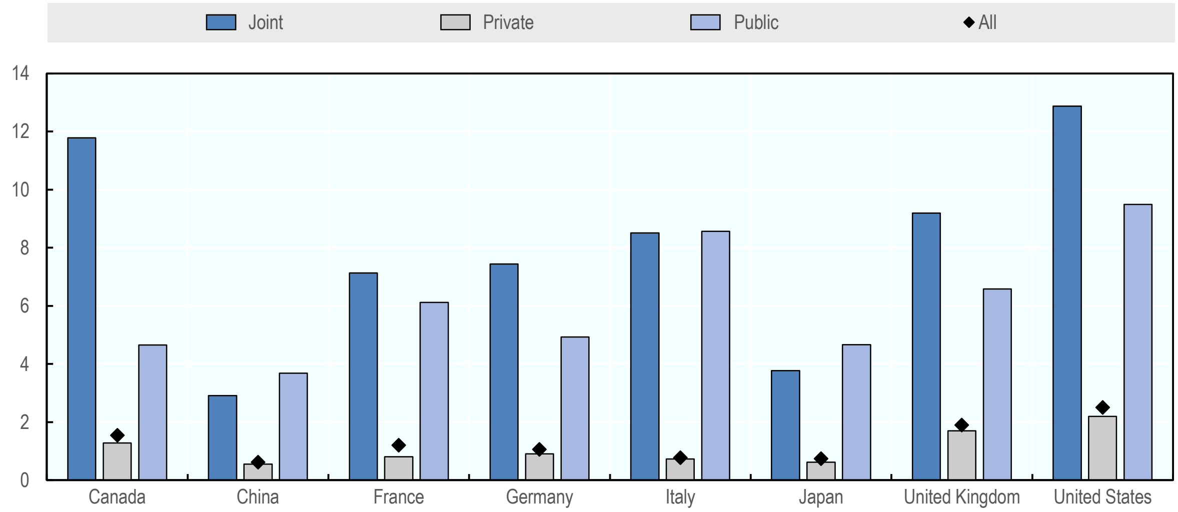
- *Basicness* – Basic or fundamental inventions describe properties, structures and relationships in nature, and formulate hypotheses, theories or laws.
- *Scope* – An invention with large general scope permits advances in a wider range of scientific and technological fields.
- *Impact* – High-impact inventions advance the knowledge frontier, and can have profound effects on firms, industries, and markets.

HEIs and PRIs engage in basic research, which is often government sponsored particularly where it is seen too risky for private enterprises. Basic research may require longer periods to be translated into commercial technologies, which creates uncertainty for firms. On the other hand, research conducted at HEIs and PRIs can inform a wide range of scientific and technological fields. Therefore, public research conducted at HEIs and PRIs would be expected to be more basic, have a wider scope, and be more impactful (as per the definitions presented here). These concepts may of course be related.

Regarding basic inventions, the average patent of HEIs and PRIs (from public research) has a higher number of citations of non-patent literature (NPL) than private sector patent applications (Figure 2.7). NPL literature includes scientific publications, so that a patent with higher citations of NPL can be considered science-based or basic. Patents of HEIs and PRIs make more intensive use of state-of-the-art scientific literature than private patents. Another possible explanation behind differences in the number of patent citations to NPL could be that the public research sector files patents more often in technology fields that are themselves more science-based. Data for Japan confirm these differences: around 70% of private sector patent applications to EPO over 1992-2013 correspond to the technology classes of computer and communications, electrical and electronics, and mechanical, while 50% of applications from HEIs and PRIs and joint HEI/PRI-private patenting applications correspond to drugs and medical, and chemistry.

Figure 2.7. **Average number of patent citations of non-patent literature, selected countries**

2003-2013



Source: Fujishiro, R., "The patenting behaviour of Japanese public sector patent applicants", unpublished mimeo. OECD calculations based on the EPO Worldwide Statistical Patent Database (PATSTAT) (2018).

Data also show that the mean number of citations to NPL has increased over time, both in private and public research patent applications. Such increases could be explained by the fact that more science knowledge is progressively needed to create a patent application that satisfies the novelty requirements, given today's rapid technological advances.

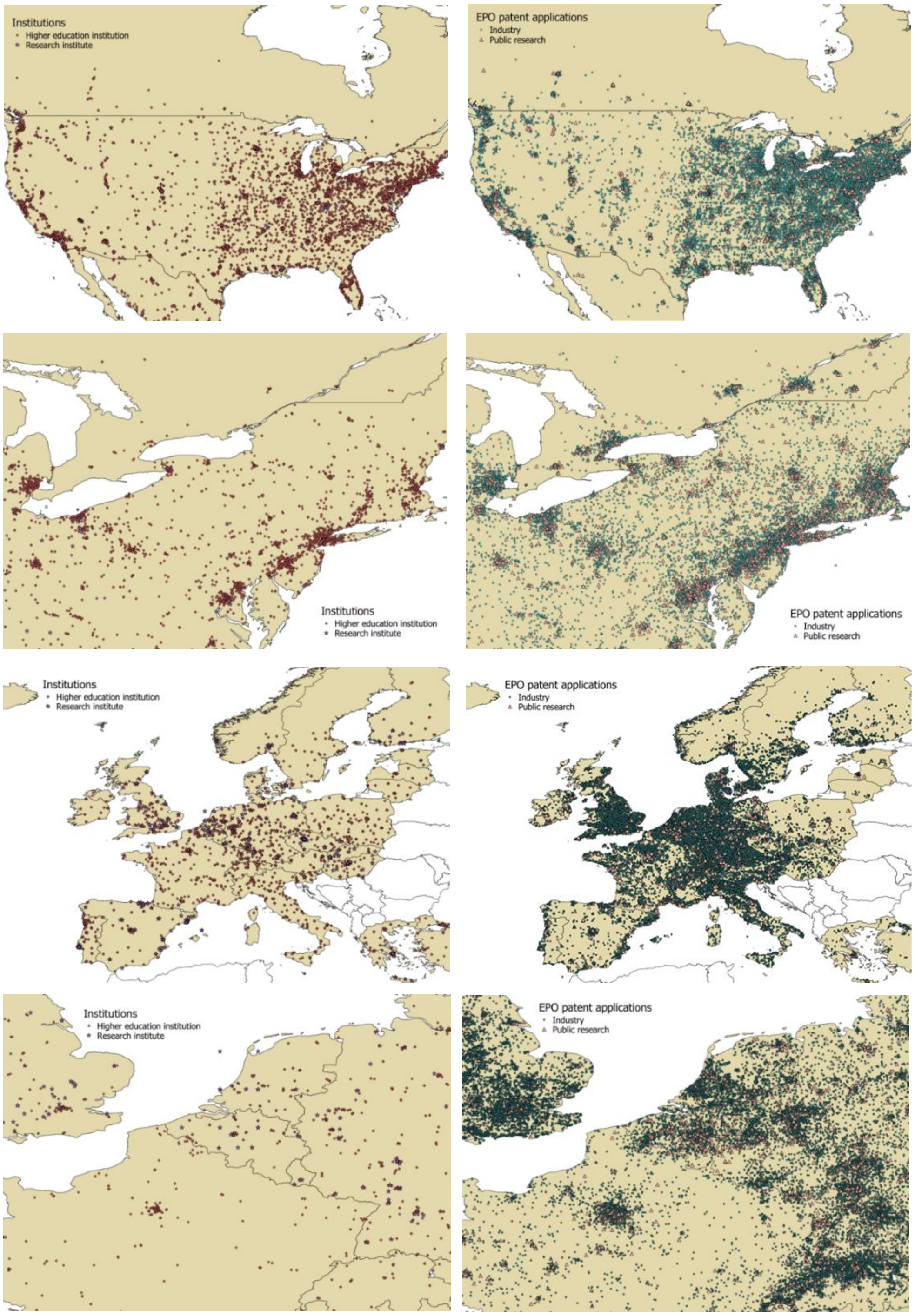
2.2. Does proximity to public research matter for industry inventions?

This section explores the causal linkages from public research to industry inventions using information on the geographical location of institutions, which is arguably exogenous to current business dynamics.

Proximity matters for knowledge flows between industry and science. Seminal work on these flows in the United States has shown that citations from industry patents to university research publications, for instance, increase with proximity to those universities (Jaffe, Trajtenberg, and Henderson, 1993). The importance of geographic proximity has not changed since the 1990s, notwithstanding the arrival of the digital technologies that reduced the costs of long communication over longer distances (Figueiredo, Guimarães, and Woodward, 2015). Belenzon and Schankerman (2013) use US patent and citation data for the years 2002-07 to show that citations from corporate patents to university publications and patents are locally bound, and decline sharply with distances over 100 miles from a university.

Statistics based on the database of 21 619 HEIs and PRIs produced for this project show that industry inventors reside in geographical proximity to universities and PRIs. Fifty percent of all inventive activity of industry in the 36 countries in the database – as measured by the address of the inventors – occurred within 30 kilometres' distance from a university or PRI (Figure 2.8).

Figure 2.8. **Locations of higher education institutions and research institutes and of inventors from public research and industry**



Note: Figures on the left show the locations of higher education institutions and public research institutes, while figures on the right shows the locations of inventors from industry and from public research institutions.

Source: OECD calculations based on the European Tertiary Register (ETER, 2018), Integrated Postsecondary Education Data System (IPEDS, 2018), Register of Public-Sector Organizations (OrgReg, 2018) World Higher Education Database (WHED, 2018), and the EPO Worldwide Statistical Patent Database (PATSTAT) (2018).

Proximity to universities matters, but does it lead to more innovation? Proximity could simply reflect co-location of universities and firms in dynamic clusters. To identify impacts of universities on local industry patent growth, an analysis using the geographical location of universities that were established around mines in the 19th century was conducted. The historical location decision of universities is not influenced by modern economic conditions. The world's first technical university, the Selmecbánya (Berg-Schola) (today's University of Miskolc),[2] was founded around the mining sites of Selmecbánya in Austria-Hungary (today's Slovak Republic) in 1735. The first German institute of technology, the Braunschweig University of Technology, was established as Collegium Carolinum due to its geographical proximity to mining sites in 1745 (Albrecht, 1982). The needs of the Industrial Revolution influenced their location choice, as the newly opened mines and the emerging manufacturing industries in their surroundings required educated engineers and skilled technical workers. Throughout the 20th century, industrial and structural change have shifted the centres of industrial invention away from these mining sites, rendering those sites less tightly connected to the innovation dynamics found in modern locations.

Evidence using data on mining sites located mostly in the United States that were established in 1900 or before point for to a positive significant effect of proximity to nearest university on the growth rate of industry EPO patent application between 1992 and 2014, where proximity to a university is instrumented by using proximity to the nearest historical mine site (established in 1900 or earlier).

2.3. Public research and innovative entrepreneurship

This section addresses student and researcher start-ups ("academic start-ups"), another important channel for knowledge transfer that involves students and researchers. The section is based on data for 40 363 start-ups across 20 countries, i.e. 16 OECD countries plus Brazil, China, India, and Russia, for the period 2001-16. The source is the database Crunchbase,[3] which gathers information on start-ups and their founders across the OECD area. Importantly, it differentiates between student start-ups and researcher start-ups, defined as those established by a PhD student or a researcher. The data provide interesting perspectives on entrepreneurship activity but are not comparable to census information (see Annex 2.A1). There are three types of start-ups in this global category: companies founded by a pre-doctoral student; by a PhD holder; and by a researcher. For detailed information about the data and methods, see Breschi et al., forthcoming.

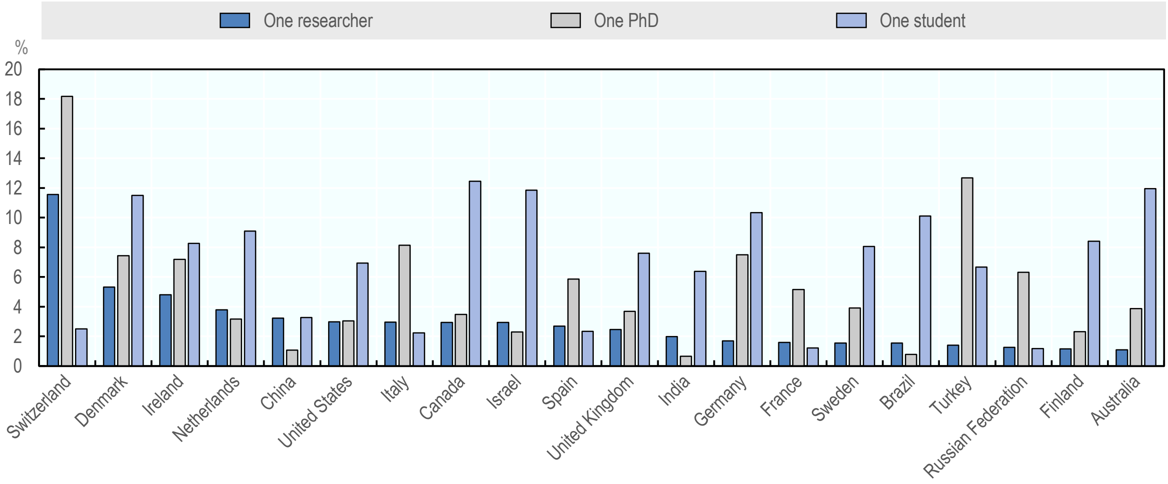
Academic entrepreneurship is a significant component of the innovative entrepreneurship ecosystem of Crunchbase. Academic start-ups account for more than 20% of all start-up activity in science-based technology fields (e.g. biotech), and around 14-15% of start-up activity overall. Academic start-ups are those established by recent university graduates, doctorate students, and academics.[4]

The share of academic start-ups on Crunchbase is particularly high in science-based technological fields – for example, they account for 23% of all innovative start-ups in biotechnology. Biotechnology also clearly stands out as the field with the highest incidence (14%) of start-ups founded by former researchers, while education, apps, and transportation are characterised by relatively high shares of student entrepreneurship.

While in biotech most founders of academic start-ups are experienced researchers, across other fields they are more often undergraduate students. Figure 2.9 shows that student start-ups on Crunchbase account for the highest share of academic start-ups in most countries. There are important differences across countries in the share of different types of academic start-ups.

Figure 2.9. **Share of academic start-ups in total start-ups by country and type of academic entrepreneur**

2001 - 2016

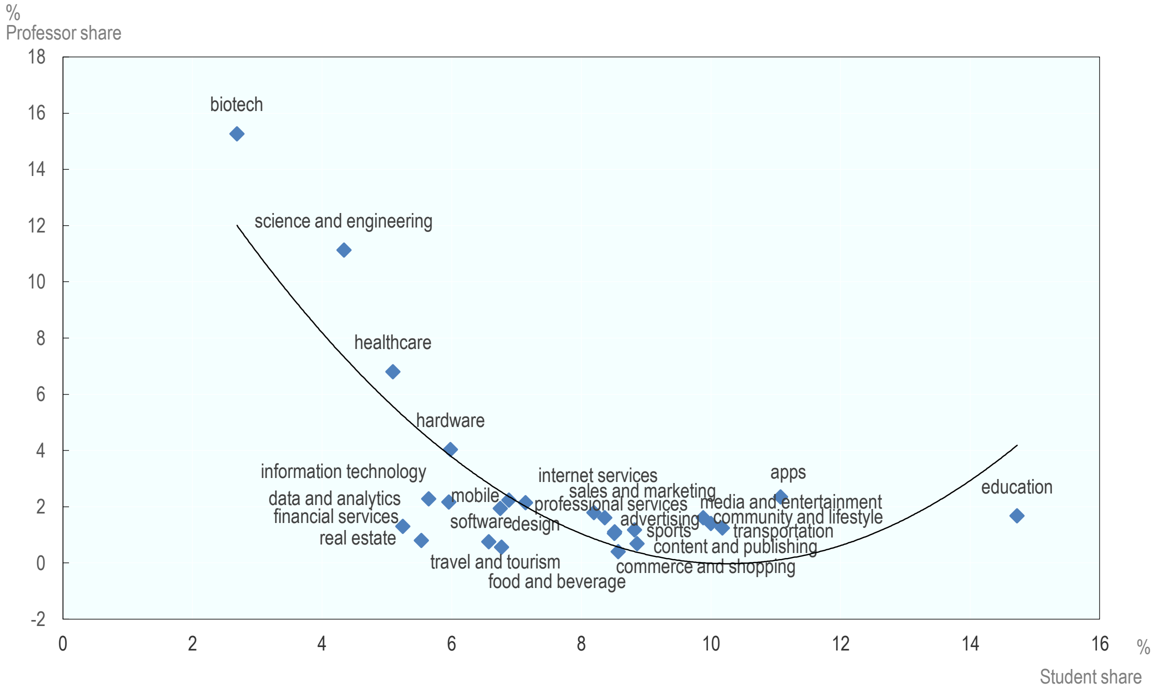


Note: The sample is limited to companies created after 2001 and having received at least one venture capital investment. The graph is limited to the top 20 countries in terms of start-up numbers.
Source: Breschi *et al.* (forthcoming) based on Crunchbase database (www.crunchbase.com).

Technology fields with higher shares of researcher start-ups do not attract student start-ups, suggesting trade-offs at play between these two channels of academic entrepreneurship. Figure 2.10 illustrates the relationship between professor- and student-founded start-ups by the means of scatter plot. The relationship between the two variables is non-linear, especially across technologies. Some technological fields characterised by high shares of start-ups founded by professors may show a relatively low incidence of student entrepreneurship, as is the case with biotechnology. Conversely, students are responsible for academic entrepreneurship in sectors like finance and real estate.

Figure 2.10. **Professor-founded vs. student-founded start-ups, by technological field**

2001 - 2016



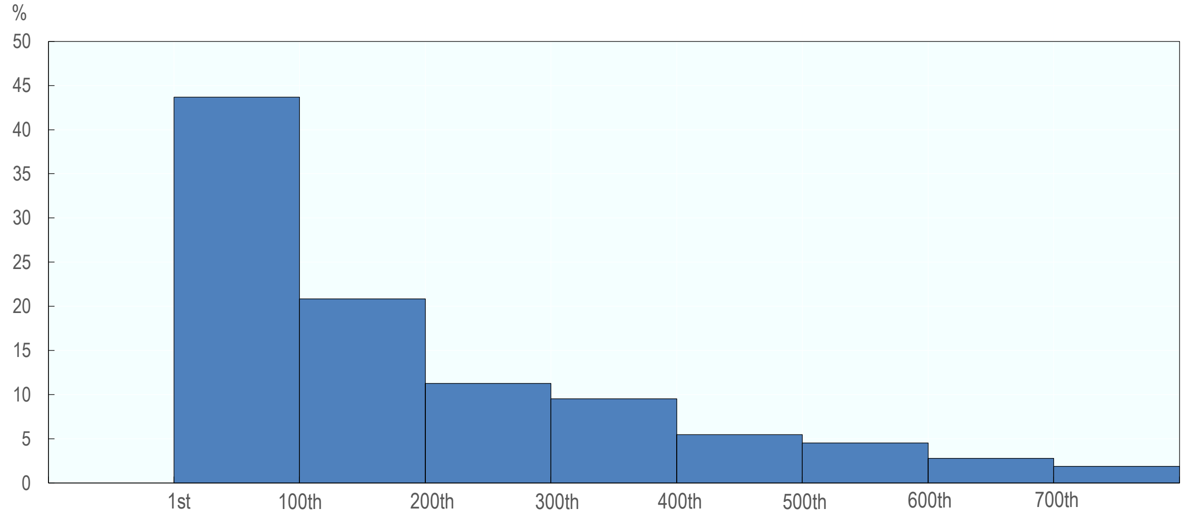
Note: The figure illustrates the relationship between the share of start-ups established by students and that established by professors in total start-up numbers across technology classes. The sample is limited to companies created after 2001, located in OECD or BRIICS countries, and having received at least one venture capital investment. Graph limited to the top 25 technologies in terms of start-ups numbers.
Source: Breschi *et al.* (forthcoming) based on Crunchbase database (www.crunchbase.com).

Start-ups founded by PhD students and academic researchers are significantly more likely to patent than non-academic start-ups. Student start-ups, however, tend to patent less often than the average non-academic start-up. Students tend to establish start-ups in service-oriented fields such as education, apps and transportation, where patenting is not as common as it is in other channels of knowledge transfer. Among patenting start-ups, academic start-ups have patent portfolios that are closer to science as measured by citations to scientific literature.

Academic entrepreneurship is still concentrated in a few leading universities. Figure 2.11 shows that across the sample analysed, the leading 100 universities as measured by the CWTS Leiden ranking[5] produce 45% of all academic founders of start-ups on Crunchbase.

Figure 2.11. **Percentage of academic founders of start-ups by rank of their home university**

2001 – 2016



Note: The sample is restricted to founders for whom the alma mater university is reported and can be linked to a university appearing in the Leiden ranking. This ranking uses bibliographic data from the Web of Science database produced by Clarivate Analytics. The measure used in this chapter relies on the proportion of a university's publications that, compared with other publications in the same field and in the same year, belong to the top 10% most frequently cited.
Source: Breschi *et al.* (forthcoming) based on www.crunchbase.com and EPO Worldwide Statistical Patent Database (PATSTAT) (2018) data.

Academic entrepreneurs are likely to be located within the same urban areas as the university that they graduated from, which points to the importance of spatial proximity for academic entrepreneurship. Data on the location of Canadian start-ups show that academic start-ups are more likely to be located in the same city (i.e. Functional Urban Area) as their home university, while non-academic start-ups depend less on proximity to universities. Academic start-ups may benefit from proximity to their home university as proximity gives them access to academic networks.

Evidence points to the role of spatial proximity in facilitating the knowledge flow from research institutions to academic start-ups, especially for highly innovative business ventures. Among the sample of patenting Canadian start-ups, academic start-ups show a higher probability of being located in the same city as the home university of their founder than non-academic start-ups.

2.4. Conclusions

Assessing the impacts of universities and public research institutions on innovation and entrepreneurship is important for designing policies aimed at strengthening knowledge transfer between research institutions and industry. Evidence from new analysis of micro data on patenting and start-ups from across the OECD area shows that HEIs and PRIs contribute to innovation by patenting their own technical inventions and by engaging in joint patent activity with industry. PRIs and HEIs also stimulate start-ups established by researchers and students, which are a significant component of the innovative entrepreneurship ecosystem.

An analysis of locational information of inventors and universities shows that inventive businesses and innovative start-ups also locate around universities, suggesting that spillovers from university research can have major economic effects. An impact assessment using information on the establishment of universities, and proximity of universities to historical mining sites, suggests that proximity to universities boosts industry inventions in OECD member countries.

Results from this cross-country impact assessment using micro data, although useful, shed light on specific aspects but not all dimensions of knowledge transfers. The near future may provide fresh insights on additional knowledge transfer channels between science and industry, but not without comparable, cross-country information on science-industry linkages, including industry-funded R&D, joint research projects, and new intermediaries for knowledge co-creation. For instance, linking existing databases on research institutions to publications and research projects is a promising avenue for analysing co-creation activities involving science and industry. Matching university and research institution data to new indicators of governance of public research (see Chapter 6) will also help in analysing the role to be played by policy and institutions for knowledge transfer.

Notes

[1] www.kauffman.org/microsites/state-of-the-field/topics/finance/equity/venture-capital accessed on 11 September 2017.

[2] History of the University of Miskolc, available at www.uni-miskolc.hu/uni/univ/booklet/MandU.html (accessed on 20 February 2019).

[3] www.crunchbase.com.

[4] Founders are defined as a student founder if they created a company within four years after the start of their undergraduate studies. PhD founders need to have created a company within seven years after embarking on their PhD programme. Founders reporting at least one job experience as a “post-doc”, “lecturer”, “professor”, and similar job titles, who founded the company within three years after the end of their research experience, are classified as researcher founders.

[5] The Leiden ranking of universities measures the proportion of a university’s publications that are in the top 10% of publications most frequently cited in their field. It is independent of university size.

References

Aldrige, T. and D.B. Audretsch (2010), "Does policy influence the commercialization route? Evidence from National Institutes of Health funded scientists", *Research Policy*, Vol. 39, pp. 583-588.

Andersson, R., J.M. Quigley and M. Wilhelmsson (2009), "Urbanization, productivity, and innovation: Evidence from investment in higher education", *Journal of Urban Economics*, Vol. 66, pp. 2-15.

Belenzon, S. and M. Schankerman (2013), "Spreading the word: Geography, policy and knowledge spillovers", *The Review of Economics and Statistics*, Vol. 95, pp. 884-903.

Borowiecki, M. and C. Paunov (2018), "How is research policy across the OECD organised? Insights from a new policy database", *OECD Science, Technology and Industry Policy Papers*, No. 55, OECD Publishing, Paris, https://doi.org/10.1787/235c9806-en.

Breschi, S., J. Lassébie, A. Lembcke, C. Menon, and C. Paunov (forthcoming), "Public Research and Innovative Entrepreneurship: Cross-country evidence from micro-data", *OECD Science, Technology and Industry Policy Paper.*

Dalle, J., M. den Besten and C. Menon (2017), "Using Crunchbase for economic and managerial research", *OECD Science, Technology and Industry Working Papers*, No. 2017/08, OECD Publishing, Paris, https://doi.org/10.1787/6c418d60-en.

Della Malva, A., F. Lissoni and P. Llerena (2013), "Institutional change and academic patenting: French universities and the Innovation Act of the 1999, *Journal of Evolutionary Economics*, Vol. 23, pp. 211-239.

Elsevier (2018), Scopus database (database).

European Patent Office (2018), *EPO Worldwide Statistical Patent Database* (PATSTAT) (database).

Figueiredo, O., P. Guimarães and D. Woodward (2015), "Industry localization, distance decay, and knowledge spillovers: Following the patent paper trail", *Journal of Urban Economics*, Vol. 89, pp. 21-31.

Geonames (2018), Geonames Geographical Database (database), https://www.geonames.org/ (accessed 27 April 2018).

Institute of Education Sciences (2018), Integrated Postsecondary Education Data System (IPEDS) (database), https://nces.ed.gov/ipeds/ (accessed 27 April 2018).

International Association of Universities (2018), World Higher Education Database (WHED) (database), http://whed.net/home.php (accessed 27 April 2018).

Jaffe, A., M. Trajtenberg and R. Henderson (1993), "Geographic localization of knowledge spillovers as evidenced by patent citations", *Quarterly Journal of Economics*, Vol. 108, pp. 577-598.

Kantor, S. and A. Whalley (2014), "Knowledge spillovers from research universities: Evidence from endowment value shocks", *Review of Economics and Statistics*, Vol. 96, pp. 171-188.

Annex 2.A1

Data used for the cross-country comparison

Results reported in Sections 2.1 and 2.2. are based on a database of HEIs and leading PRIs and their patent activity for 36 countries – 35 OECD countries and China. The data have 21 619 observations on public research institutions, including 20 583 universities and 1 036 PRIs, and 2 550 191 patent applications at the European Patent Office (EPO) and their inventors for the 1992-2014 period.

Information on HEIs and PRIs is taken from the following data sources: (1) The European Tertiary Education Register (RISIS Consortium, 2018a) provides census information on higher education institutions with more than 200 students for 26 European OECD member countries, (2) the Integrated Postsecondary Education Data System (Institute of Education Sciences, 2018) collects census information on U.S. higher education institutions that receive federal student grants, (3) the World Higher Education Database (International Association of Universities, 2018) covers universities outside Europe and the U.S. as reported by national authorities to the UNESCO, (4) the Register of Public-Sector Organizations (RISIS Consortium, 2018b) collects information on public research institutions with more than 30 R&D personnel from 26 European countries (the same list of countries as in the ETER database), and (5) the Scopus database (Elsevier, 2018) provides a list of the names of leading public research institutions in terms of scientific publications outside Europe. Information on EPO patent applications filed by inventors resident in the 36 countries is taken from the EPO Worldwide Statistical Patent Database (PATSTAT) (2018) and the OECD REGPAT database (2017). OECD REGPAT (2017) provides regionalised EPO patent information, including postal codes of applicants and inventors.

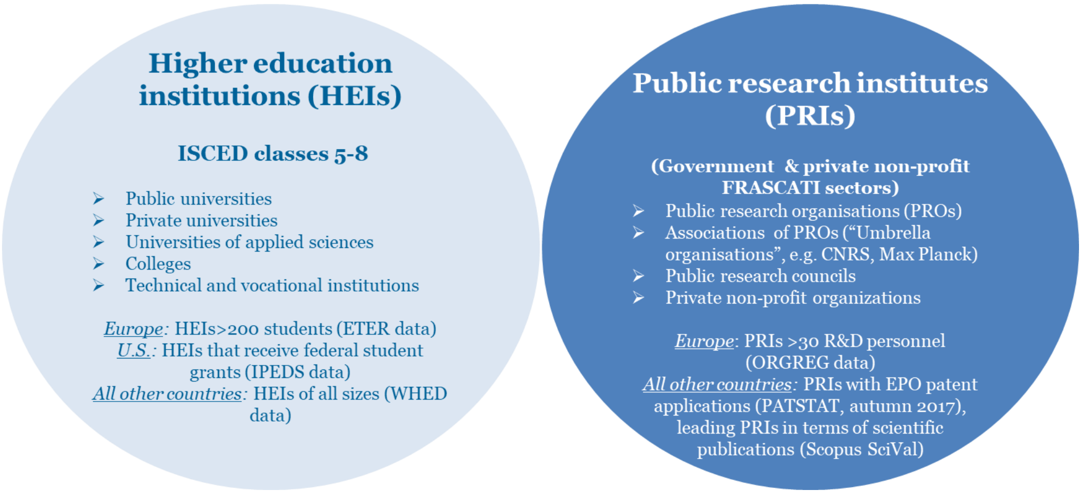
Data on the precise geographic latitude and longitude coordinates of postal codes (so-called geo-information) complements the analysis and is taken from the Geonames (2018) database. The geo-information is matched to postal code information of HEIs, PRIs and inventors to create measures of geographical distance to universities. Data on historical mining sites is used to construct instruments for distance to university in order to account for possible endogenous university location. Data on mining sites for the OECD and China come from the U.S. Geological Survey (2018). Finally, the study complements patent, university and PRI survey information with additional information on night light luminosity from the National Geophysical Data Center (2018) of the U.S. National Oceanic and Atmospheric Administration. Night light luminosity data is used as a proxy for economic activity at postal code levels for which economic data is not available.

Regarding coverage, the database includes public universities, private universities, universities of applied sciences, colleges, and technical and vocational institutions of ISCED classes 5-8. With regard to PRIs, the dataset includes public research organisations (PROs), their associations, public research councils, and private non-profit organisations performing research.

There are some caveats to the university and PRI data, particularly for smaller HEIs and PRIs. While all PRIs with 30 or more R&D personnel in Europe are included, only information on leading PRIs – defined as PRIs with strong publishing and patenting performance – outside of Europe was available. Data on leading PRIs were retrieved based on publishing information in Scopus SciVal (Elsevier, 2018). All PRIs with at least one patent application as included in the EPO Worldwide Statistical Patent Database

(PATSTAT) (2018) were also included. Moreover, the coverage of universities across countries differs slightly due to different selection criteria adopted by source surveys (Figure 2.A1.12). More information on the data is provided in Borowiecki, El-Mallakh and Paunov, 2019.

Figure 2.A1.12. **Coverage of public research institutions**



Results reported in Section 2.3. are based on data taken from Crunchbase,[1] which provides information on academic start-ups, i.e. start-ups established by students, PhDs and researchers, using data on 40 363 start-ups across 20 countries, including 16 OECD countries plus Brazil, China, India, and Russia, for the period 2001-2016. Crunchbase contains information on companies and their funders, including their university background.[2] Important additional project work (Breschi et al., forthcoming) consisted in matching start-up information to the database of 21 619 public research institutions (20 583 HEIs and 1 036 PRIs), based on an original approach that exploits educational information of the founders of start-up activities.

Several limitations apply to the Crunchbase database. First, the data do not represent a census. The coverage appears particularly large for start-ups operating in digital-related sectors (e.g. data analytics, apps), where venture capital investors are largely present. Its coverage of is not clearly defined and may vary significantly across countries and sectors. Second, the database does not contain information of start-ups that failed and ceased operations, nor are all companies reported in Crunchbase start-ups; for example, several large and old corporations also appear in the database, especially if they are acquirers of start-ups.

More information on the data is provided in Breschi et al. (forthcoming) and in Dalle, den Besten and Menon, 2017.

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[1] www.crunchbase.com.

[2] While education history is not available for the full sample of listed individuals, the data allow analysis of the curricula vitae of approximately 130 000 people listed as founders or managers of more than 25 000 start-ups.

Chapter 3. Gauging social science graduates’ contributions to knowledge exchange with industry

This chapter explores a new approach to assessing knowledge transfer using labour force survey data, and applies it to assess the contributions of graduates in social sciences to different industries. It first briefly describes the challenges in assessing social scientists’ contribution to knowledge transfer and industry innovation. It then provides evidence on how graduates in social sciences contribute to different economic sectors compared to those in other disciplines, building on existing evidence based on patent data and case studies, and then exploiting new evidence from labour force surveys. The chapter discusses the advantages of using this approach for capturing the flow of human capital from university to industry, and outlines the caveats.

Introduction

The importance of specific knowledge transfer channels varies across science fields and industry sectors. Some studies show that patenting and licensing are very important for researchers in materials science and chemical engineering, but considerably less so for those in computer sciences. Contract and collaborative research and the flow of students from university to industry have been found to be highly relevant in engineering disciplines, while personal contacts and labour mobility have greater relevance in social sciences (Bekkers and Bodas Freitas, 2008; Schartinger et al., 2002).

Measuring knowledge transfer between all different science fields and economic sectors is thus a challenging task, given that academic disciplines engage differently with industry. Furthermore, some channels are particularly difficult to capture. Existing studies assessing the links between science and industry – mostly using patent data or case study evidence –mainly capture formal channels of interaction. Studies based on patent data in particular tend to be biased towards technical innovation and disregard the contributions of social sciences. Case studies have also mainly focused on exploring the contributions of STEM (science, technology, engineering, math) fields.

This chapter examines the role of social science graduates in science-industry knowledge transfer compared to individuals with other academic backgrounds, based on new evidence from labour force surveys.

The chapter finds that evidence from labour force surveys helps provide a more complete picture of knowledge transfer between science and industry, given that i) they capture the flow of human capital from university to industry, often considered one of the most important channels of science-industry interaction, and ii) they capture the full spectrum of science fields and industry sectors. An important caveat, however, is that those surveys do not directly allow identification of personnel involved in innovation activities, especially when individuals with postgraduate degrees cannot be distinguished.

The chapter – which is based on Paunov, Planes-Satorra and Moriguchi, 2017 – is organised as follows. Section 3.1 discusses why the contributions of social sciences to industry innovation are particularly challenging to capture. Section 3.2 explores how graduates in social sciences contribute to different economic sectors compared to graduates in other disciplines. Section 3.3 concludes.

Figure 3.1. Synthesis of chapter 3

HOW DO SOCIAL SCIENCES CONTRIBUTE TO INNOVATION?

WHY IS IT DIFFICULT TO ASSESS THE CONTRIBUTION OF SOCIAL SCIENTISTS TO INNOVATION?

Diversity of contributions to innovation

Social scientist contribute critically to the diffusion and adaptation of innovation, as well as the implementation of process and organizational innovations. However, these are challenging to quantify.

Soft skills

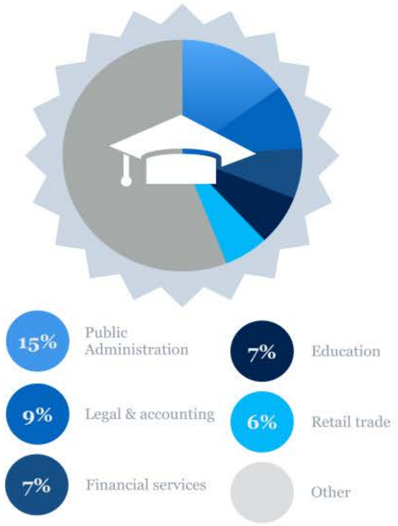
Social scientists often provide soft skills that are key for innovation, but are difficult to fully capture (e.g. creative & critical thinking, communication skills)

HOW TO ASSESS THEIR CONTRIBUTION TO INNOVATION?

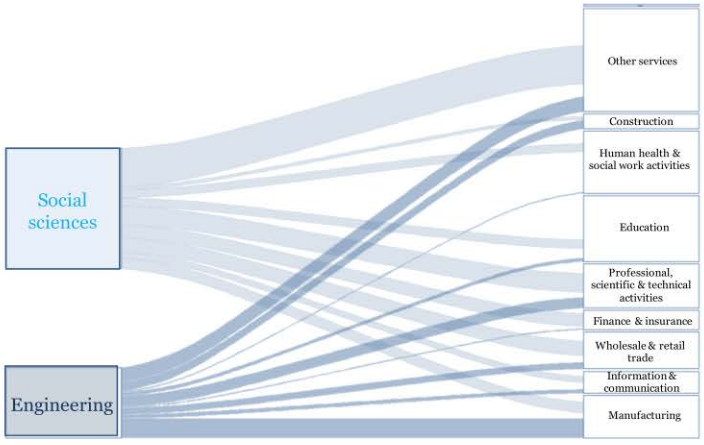
Traditional approaches		*New methods*	
PATENT DATA ANALYSIS	**CASE STUDIES**	**LABOUR FORCE SURVEYS**	**FUTURE AVENUES**
Mainly capture contributions to technical innovation, thus underestimating contributions of social sciences	May capture social sciences contributions, but most mainly document contributions of science, technology, engineering, and mathematics (STEM fields)	Allow identifying the sector of employment of graduates in all fields, an indicator of science-industry knowledge transfer, but do not assess involvement in innovation	New data and big data analysis offers new opportunities (e.g. web scraping of online job advertisements allows exploring demand for social scientists)

SECTORS OF ACTIVITY OF GRADUATES IN SOCIAL SCIENCES (EU-28,2013)

Main sectors of activity for graduates in social sciences



How do sectors of activity of social scientists compare to those of engineers?



3.1. Challenges in assessing social scientists' role in knowledge transfer

Social sciences cover a range of disciplines concerned with the study of society and the ways in which individuals behave and interact with each other. These include law, economics, political science, demography, sociology, geography, psychology, anthropology, journalism and information sciences, and business and administration. While social scientists constitute the largest share of tertiary graduates in many countries (for example accounting for an average of 29% of graduates in EU-28 countries in 2013), there have been relatively few studies on the relevance of knowledge transfer between social sciences and industry (Gulbrandsen, Mowery and Feldman, 2011).

There are several reasons why the contributions of social scientists are more difficult to measure than the contributions of those in natural sciences, engineering, or medical and health sciences (see discussions in Bastow, Dunleavy and Tinkler, 2014; British Academy, 2010). First, social scientists may contribute to improving firms' processes and organisation, as well as to developing innovative practices to adapt to changing demands in the context of the digital transformation. Social scientists may also positively affect the launch of new products and services by introducing innovative marketing strategies; by finding new ways of interacting with customers; and by strengthening business networks. Thus while directly supportive of innovation, their contributions are more indirect and consequently more difficult to capture. Second, consultancies often play an important intermediary role in applying insights from social science research to industry needs. Thus the impact of social science research may in some cases come less through immediate application of research results. Third, social scientists provide industry not only with discipline-related skills, but often also with a range of soft skills that are key for innovation, including creative and critical thinking and the ability to communicate and to identify new opportunities.

Given these characteristics, science-industry knowledge transfer in fields of social science often do not take the form of commercialisation activities (such as patenting, licensed research and spin-offs) or direct research co-operation, but rather that of problem-solving activities (e.g. consultancy services), personnel mobility, and other more informal channels of interaction (e.g. giving lectures, participating in networks) (Schartinger et al., 2002). The linkages to innovation are thus more indirect and difficult to capture.

3.2. Evidence of social science graduates' contribution to different industries

This section explores how graduates in social sciences contribute to different economic sectors compared to graduates in other disciplines. It first presents an overview of existing evidence based on patent data and case studies, and then provides new evidence from labour force surveys.

What we know from patent data analyses and case studies

Existing literature on science-industry linkages, mainly based on patent data and case study evidence on technology-driven industries, suggests that social sciences play a minor role in industry innovation compared to STEM disciplines. Statistics on patent citations to non-patent literature (NPL) for 2001-11 (see Paunov, Planes-Satorra and Moriguchi, 2017) show that social science literature is not cited in patents in practically any industry sector, with the exception of patents in IT methods for management; in fact, social sciences account for only 4% of total citations to NPL. This contrasts with disciplines such as chemistry or engineering that contribute to patents (and thus innovation) in a wide array of sectors.

These findings are however partly explained by the fact that patent citations mainly capture contributions to technical innovation (i.e. suitable for patenting). The contributions of social sciences to advances allowing implementation of technical inventions, for instance, are not captured, as patents cover only the technical dimensions of an invention, not the social or human dimensions. Nor do they capture non-technological innovations, to which social sciences contribute more.

Existing case studies mainly document the contributions of STEM fields (Paunov, Planes-Satorra and Moriguchi, 2017). The limited available evidence focusing on social sciences suggests that economics and business are the social science disciplines that have the highest impact on industry, contributing especially to business and financial and insurance services. Schartinger et al. (2002) suggest that other social sciences (law, psychology and geography) contribute to a few sectors only.

By contrast, case studies find that chemistry, materials science, computer science and different engineering fields contribute to a wide range of economic sectors, including the computer, communications and software industries. Research in biology is particularly important for pharmaceuticals producers as well as for producers of pesticides, medical equipment and water treatment industries. Disciplines that are found to make important contributions to a fewer range of industries include medical science, pharmacology, agricultural science and geology. More fundamental sciences are also found to matter for industry. Among others, the physical sciences are important to the semiconductors, computer and medical equipment industries; and mathematics are crucial to search and navigational equipment, electronic components, semiconductors and the aerospace industries.

Insights from labour force surveys

This section presents new evidence on the contributions of graduates in social sciences to different industry sectors, as compared to other academic fields, based on the use of labour force survey data from two sources (the EU Labour Force Survey and the UK Quarterly Labour Force Survey). The evidence identifies the sector of employment of graduates in different science fields (see the methodological note in Annex 3.A1). Results are interpreted as an indicator of the flow of graduates from specific academic disciplines to different industry sectors, often considered the most important channel of science-industry knowledge transfer (OECD, 2013).

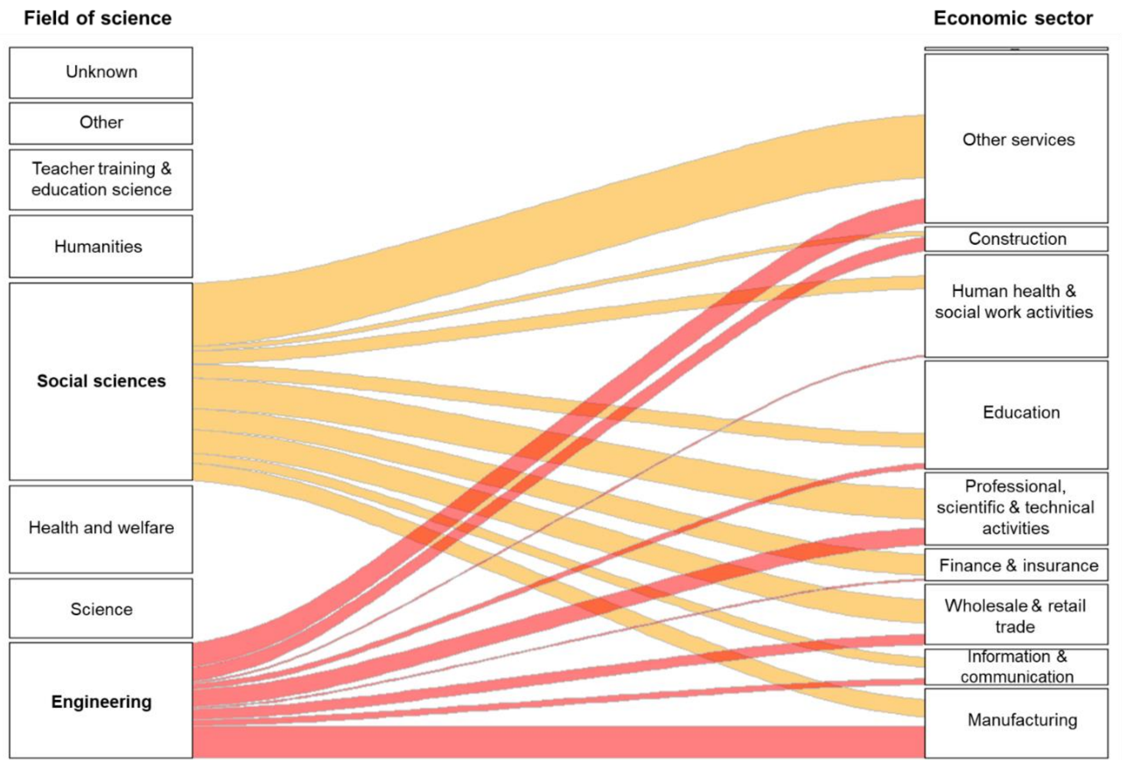
A main drawback of these surveys is that they do not distinguish graduates by their level of academic attainment (i.e. bachelor's, master's or doctoral degree). Identifying masters and doctorate holders in surveys would produce a more accurate picture of contributions of specific science fields to innovation in industry sectors, as the likelihood of those individuals being engaged in innovation activities is higher than persons with bachelor degrees only.[1] Introducing questions in labour force surveys that help measure involvement in innovation activities and track academic attainment would deepen understanding the nature of industry-science linkages.

Contributions of graduates in social sciences to different sectors, compared to graduates in other disciplines

Data from the EU Labour Force Survey for 2013 show that industry destination differs significantly across disciplines, with social scientists comparatively less involved in manufacturing activities (see Table 3.A2.1). They are employed mainly in the public administration (15%) and education (7%) sectors, as well as in several service sectors, notably legal and accounting activities (9%), financial services (7%) and retail and wholesale trade (6% and 5%). Education and public administration are also main sectors of employment for graduates in physical sciences, life sciences and mathematics.

In contrast to social scientists, graduates in engineering are employed in architectural and engineering activities (11%) as well as in construction-related and manufacturing activities. Approximately one-third of graduates in computer sciences are engaged in computer programming, consultancy and related activities (29%). A relatively high share of life scientists work in human health activities (11%), while scientific research and development activities are frequent destinations for graduates in both life sciences and physical sciences (9% and 7%, respectively) (see Annex 3.A2).

Figure 3.2. **Economic sector destinations of graduates in social sciences and engineering, EU-28, 2013**



Note: The width of linkages reflects the relative size of connections. Fields of science correspond to the ISCED classification of 1997. "Social sciences" includes social and behavioural sciences (economics, political science, sociology, demography, geography and anthropology), journalism and information sciences, business and administration, and law. Economic sectors correspond to the NACE Rev.2 (1-digit level) classification.

Example of how to read the figure: The largest share of Engineers (shown in the bottom left side of the figure, with flows in red colour) works in Manufacturing.

Source: European Union Labour Force Survey, 2013.

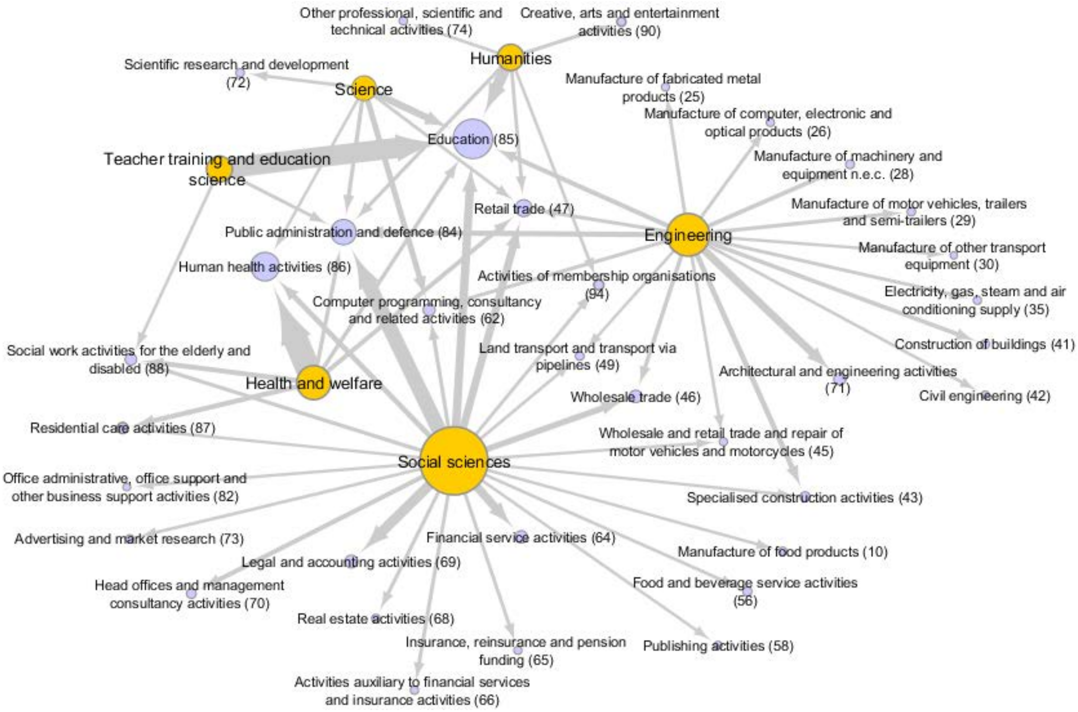
Figure 3.2 allows a clearer comparison of the flows (in absolute terms) of graduates in social sciences and engineering towards different economic sectors. Manufacturing sectors are the main destination for engineers, followed by professional, scientific and technical activities and construction activities; social scientists mainly work in the service sectors. Flows differ significantly across countries, however.[2]

To illustrate the full set of linkages and the relative importance of flows from different academic fields to industry sectors, Figure 3.3 presents a network that links each academic discipline (with its relative weight captured by the size of yellow circles) to the most common industry destinations of graduates in that discipline (with the magnitude of the flow captured by the width of the arrows). It shows that graduates in social sciences work in a wide variety of sectors – mainly in service sectors, including highly dynamic ones such as management consultancy, computer programming, and legal and financial service activities. Graduates in engineering work mostly in manufacturing industries and, as expected, most graduates in health-related studies contribute to human health activities.

Figure 3.3 also reflects to some extent the relative importance of multidisciplinary sourcing of graduates across economic sectors. Sectors at the centre of the figure (including education, public administration, human health activities, computer programming and consultancy, and wholesale and retail trade) tend to recruit graduates from a variety of academic backgrounds, suggesting that they require the contributions from different science fields. Individuals with multidisciplinary backgrounds are likely to be highly sought after by those industries. Sectors at the periphery of the figure rely more on graduates from a few specific science disciplines.

These findings are in line with those of Avvisati, Jacotin, and Vincent-Lancrin (2013) who, based on two international surveys on tertiary education graduates,[3] find that the bulk of the highly innovative workforce in business activities (including computer-related activities, research and development, consultancy and advertisement) is composed of graduates in social sciences, including business and law studies; significantly less represented are engineers (21%) and graduates in sciences and mathematics (10%). They also find that the trend is more pronounced in financial intermediation sectors, where social scientists account for more than 75% of total employees engaged in innovation activities. In manufacturing industries, they find that more than 50% of employees involved in innovation activities have an engineering/computing degree (42.9%) or a science/math degree (7.8%), while social sciences (including business studies) represent a non-negligible 30% of the total. Findings are also in line with Schartinger et al. (2002) who find that social scientists in Austria (particularly in the field of economics) especially engage in innovation-related activities within services sectors.

Figure 3.3. **Economic sector destinations of graduates in different fields of study, EU-28, 2013**



Note: Yellow circles illustrate disciplines and purple circles illustrate economic activities. The size of circles and width of arrows reflect the relative size of disciplines and connections. Only linkages involving more than 200 000 people have been included. Therefore, the figure is not exhaustive and aims at presenting a broad overview of university-industry flows that are more relevant in absolute terms. Numbers correspond to the economic activity according to the NACE Rev.2 (2-digit level) classification. Fields of science correspond to the ISCED classification of 1997.
Example of how to read the figure: Social scientists (which are in absolute terms the most numerous among those in the labour force with tertiary education in EU-28 countries) work in a wide variety of sectors. The largest share of social scientists work in the public administration sector, as illustrated by the relative width of the arrow, followed by legal and accounting activities, education, and financial service activities.
Source: European Union Labour Force Survey, 2013.

The analysis of the economic destination sectors of graduates in different social sciences using labour force data for the United Kingdom (which allows having information at a higher level of granularity) shows that state administration and the education sector are among the main destinations for graduates in all social science disciplines (and the main ones for graduates in historical and philosophical studies), together with management consultancy and activities related to social work. Significant disparities across social science disciplines are also captured: graduates in law and in communication-related studies tend to work in a few specific service sectors, while graduates in social studies (including economics, politics, sociology, social work, anthropology and geography, among others) and business studies work in a wider range of economic activities. Graduates in law mainly work in legal activities (around 30% of the total).

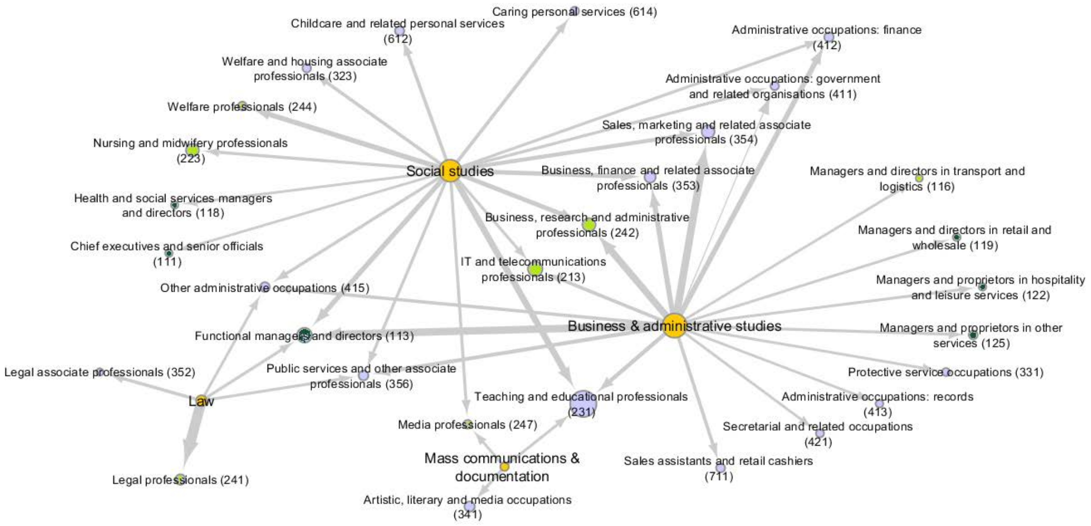
Contributions of social science graduates to innovation in different sectors

The analyses presented in previous sections focus on the sectors of employment of graduates in social sciences, but do not allow capturing whether those individuals actually contribute to innovation in those sectors – particularly when surveys do not gather information about their level of academic attainment (i.e. bachelor's, master's or doctoral degree).

This section addresses that question by providing a preliminary analysis at the occupational level, based on data from UK Quarterly Labour Force Survey data. Although occupational classifications are generic and say little about the specific tasks conducted, they can provide some hints as to whether individuals are likely to engage in more innovative activities within their sectors. This section in particular identifies individuals in managerial and professional occupations, which are considered to require creative thinking as well as the ability to identify new opportunities and implement them, among other key skills for innovation.

Figure 3.4 shows that in the United Kingdom, around 53% of graduates in social studies and 60% of graduates in law engage in management or professional occupations, while the shares are lower for those graduating in business and administrative studies (44%) and communications and documentation studies (40%). However, graduates in business and administrative studies are more likely to hold managerial positions (23% of total) than graduates in social studies, law or communications studies (16%, 9% and 7%, respectively). They are also more likely to hold managerial positions than graduates in engineering (20%), physical science (15.5%), math, computer sciences or biology (11%).

Figure 3.4. **Occupation of graduates in different social science disciplines, United Kingdom**



Note: Yellow circles illustrate disciplines and the other circles illustrate occupations. The size of circles and width of arrows reflect the relative size of disciplines and connections. Managerial occupations are presented in dark green, professional occupations in light green, and other occupations in light purple. Only linkages involving more than 10 000 people have been included. Therefore, the figure is not exhaustive and aims at presenting a broad overview of university-industry flows that are more relevant in absolute terms. Numbers correspond to the occupation according to the SOC 2010 (3-digit level) classification. Primary, secondary and higher education activities have been grouped together. "Social studies" includes economics, politics, sociology, social policy, social work, anthropology, human and social geography and other social studies.
Source: UK Quarterly Labour Force Survey, April-June 2016.

Another way of exploring the contributions of social sciences to industry innovation is by analysing the sector of employment of doctorate holders in social sciences, as these individuals are specifically trained to engage in research and innovation activities. The OECD/UNESCO/Eurostat Project on the Careers and Mobility of Doctorate Holders conducted several surveys to track the mobility patterns of PhD holders. Responses from the 2010 survey show that doctorate holders in natural sciences and engineering are more likely to be engaged in research occupations than those in social sciences. When taking into account those in research occupations only, doctorate holders in social sciences and humanities are also found in several countries to be less likely to work in the private sector (and thus less likely to contribute to industry innovation) than doctorate holders in engineering or natural sciences (OECD, 2013).

The employment patterns of doctorate holders vary significantly across countries however, most likely due to differences in employment opportunities in their respective countries (e.g. the existence or not of an innovative high-tech sector with a high demand for doctors; universities and research centres of excellence; etc.).

Contributions of social science graduates to ICT sectors compared with other disciplines

Given the current digital transformation of economies, another important question to address is the extent to which social scientists contribute to emerging sectors. This section sheds light on the issue using EU labour force survey data relating to workers in ICT sectors – which employ more than 14 million people across OECD countries[4] (OECD, 2015).

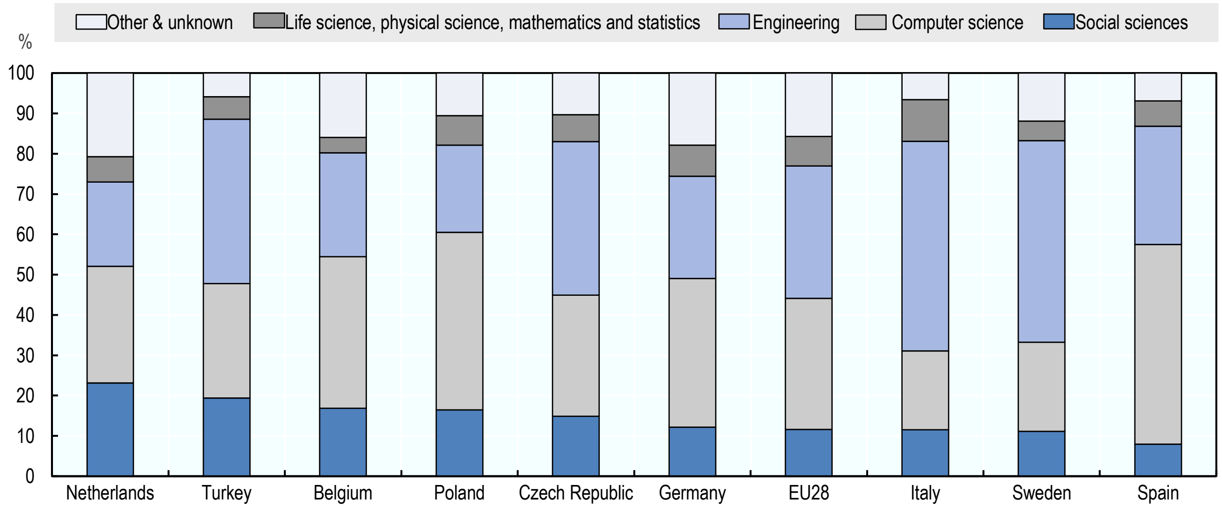
Evidence shows that in 2013, an average 24% of tertiary-educated workers in ICT sectors across EU countries had an academic background in social sciences, similar to the share of graduates in computer science (25%) and engineering (26%). There are, however, significant differences across countries. While in countries such as Spain, Sweden, Finland, Greece and Italy around 70% of workers in ICT sectors are computer scientists or engineers, in countries such as the Netherlands, Portugal and Turkey the ratio of social scientists in ICT sectors is higher than that of computer scientists.

Analysis at the occupational level using EU-LFS data shows that the share of social scientists working as ICT specialists is lower (an average of 12% of the total across the 28 EU Member States) than that of computer scientists and engineers (each accounting for one-third of the total) (Figure 3.5). Again, countries differ significantly.

This occupational analysis offers preliminary evidence suggesting that social scientists are indeed contributors to the ICT sector – yet more in-depth analysis would be needed in order to identify more precisely the extent to which they are engaged in innovation activities within the ICT and other high-growth sectors in the context of the digital transformation.

Figure 3.5. **ICT specialists by scientific discipline, European countries, 2013**

(100% = All ICT specialists in a country)



Note: ICT specialists include a number of occupations from the EU-LFS. For more details on the classification used, see Paunov, Planes-Satorra and Moriguchi, 2017.
Source: European Union Labour Force Survey, 2013.

3.3. Conclusions

Characterising knowledge transfer between specific science fields and industry sectors is important for innovation policies that aim to strengthen research contributions to industry innovation. The available evidence on science-industry linkages is seriously incomplete however, particularly as it is still largely focused on tracking linkages of high-technology manufacturing industries with STEM-based science fields. This is the case with analyses based on patent data and most survey-based case studies to date. Using new evidence from labour force surveys this chapter shows, with the example of social sciences, that these surveys – which to date have not been much used for this purpose – can help provide a more comprehensive picture of knowledge transfer, by capturing the flow of graduates from all academic disciplines to different industry sectors.

Progress in exploring science-industry linkages is possible in the near future if research explores the use of new data sources and analytical techniques to shed light on the different channels of interaction between industry and science. For example, web scraping of online job advertisements to gather systematic information on the skills sought by different industry sectors may offer new insights into interactions between specific science fields and economic sectors of activity. In addition, introducing into labour force surveys questions that help track individuals' academic attainment and their involvement in innovation activities would undoubtedly enhance use of those surveys to better understand the nature of industry-science linkages.

References

Avvisati, F., G. Jacotin and S. Vincent-Lancrin (2013), "Educating higher education students for innovative economies: What international data tell us", *Tuning Journal for Higher Education*, Issue No. 1, November, pp. 223-240.

Bastow, S., P. Dunleavy and J. Tinkler (2014), *The Impact of the Social Sciences: How Academics and Their Research Make a Difference*", SAGE.

Bekkers, R. and I.M. Bodas Freitas (2008), "Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter?", *Research Policy*, Elsevier, Vol. 37, pp 1837-1853.

British Academy (2010), *Past, Present and Future: The Public Value of the Humanities and Social Sciences*, The British Academy, London.

Eurostat (2014), Quality report of the European Union Labour Force Survey 2013, *Eurostat Statistical working papers*, Luxembourg: Publications Office of the European Union, http://ec.europa.eu/eurostat/documents/3888793/6194252/KS-TC-14-010-EN-N.pdf/39a79a33-4442-49b6-b83f-f0a5e81b02ef (accessed on 22 August 2017).

Gulbrandsen, M., D. Mowery and M. Feldman (2011), "Introduction to the special section: Heterogeneity and university-industry relations", *Research Policy*, Vol. 40, No. 1, pp. 1-5.

OECD (2015), *OECD Digital Economy Outlook 2015*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264232440-en.

OECD (2013), "Careers of doctorate holders: Analysis of labour market and mobility indicators", OECD Publishing, Paris, http://dx.doi.org/10.1787/5k43nxgs289w-en.

OECD (2007), "Information economy: Sector definitions based on the international standard industry classification (ISIC 4)", OECD Publishing, Paris, www.oecd.org/sti/sci-tech/38217340.pdf (accessed on 22 August 2017).

Paunov, C., S. Planes-Satorra and T. Moriguchi (2017), "What role for social sciences in innovation? Re-assessing how scientific disciplines contribute to different industries", *OECD Science, Technology and Industry Policy Papers*, No. 45, OECD Publishing, Paris, https://doi.org/10.1787/8a306011-en.

Schartinger, D. et al. (2002), "Knowledge interactions between universities and industry in Austria: Sectoral patterns and determinants", *Research Policy*, Vol. 31, pp. 303-328.

UNCTAD (2015), "Global assessment of sex-disaggregated ICT employment statistics: Data availability and challenges on measurement and compilation", UNCTAD Technical Notes on ICT for Development, No. 4, http://unctad.org/en/PublicationsLibrary/tn_unctad_ict4d04_en.pdf (accessed on 22 August 2017).

Annex 3.A1

Methodological note

Evidence from labour force surveys presented in this chapter is based on two main data sources.

The first one is the European Union Labour Force Survey (EU-LFS) of 2013, processed by Eurostat and based on the national labour force surveys of 33 countries (the 28 EU Member States plus Iceland, Norway, Switzerland, Turkey and the Former Yugoslav Republic of Macedonia). The EU-LFS is conducted by the national statistical institutes and Eurostat centrally processes the data. Surveys are conducted quarterly and provide results for the population in private households in each participant country; yearly results are obtained as averages of the four quarters of the year.

The total sample in the 2013 EU-LFS was of 1.8 million individuals, corresponding to 0.30% of the total population (Eurostat, 2014). Data from the EU-LFS presented in this report refer to individuals with tertiary education by the science field in which they reached the highest level of academic attainment and their industry sector of employment. Data comprise 16 science fields (following the UNESCO International Standard Classification of Education [ISCED] of 1997) and all industries at the 3-digit level of NACE Rev.2. Since 2014, the variable used in the European Union Labour Force Survey to identify the field of study in which the highest level of education was completed covers only individuals who are under the age of 35 or individuals who graduated within the past 15 years. Data for 2013 have been used to cover all age cohorts.

The second source is the UK Quarterly Labour Force Survey of April-June 2016 (Office for National Statistics and Northern Ireland Statistics and Research Agency, 2017). The total sample was of around 38 000 responding households in Great Britain and 1 500 households in Northern Ireland, representing about 0.15% and 0.21% of the total population, respectively. Data from this survey, presented in this paper, refer to the UK labour force with tertiary education[5] by science field (in which they reached their highest level of academic attainment), industry of employment, and occupation. Data comprise 19 science fields; all industries at the 3-digit level of the Standard Industrial Classification (SIC) 2010; and all occupations at the 3-digit Standard Occupation Classification (SOC) 2010.

The EU Labour Force Survey has the advantage of providing cross-country evidence of science-industry flows, yet it has limitations in terms of sampling when the aim is to exploit data at high levels of disaggregation by science and/or industry field. For this reason, for sections where the objective was to explore the industry destination of graduates in specific social science fields, more disaggregate data available from the UK Quarterly Labour Force Survey have been used. The classification of academic disciplines used in this survey allows for higher disaggregation of science fields than that of the European Union Labour Force Survey.

Annex 3.A2

Top economic sector destinations of graduates

Table 3.A2.1. **Top 10 economic sector destinations of graduates across six major disciplines, EU-28, 2013**

Social sciences	Engineering	Computer sciences
15% Public administration and defence; Social security (84)	11% Architecture & engineering; Technical testing & analysis (71)	29% Computer programming, consultancy and related activities (62)
9% Legal and accounting activities (69)	6% Public administration and defence; Social security (84)	8% Education (85)
7% Financial service activities, except insurance and pension funding (64)	6% Specialised construction activities (43)	6% Public administration and defence; Social security (84)
7% Education (85)	5% Education (85)	4% Retail trade, except in motor vehicles and motorcycles (47)
6% Retail trade, except in motor vehicles and motorcycles (47)	4% Manufacture of machinery and equipment n.e.c. (28)	4% Financial service activities, except insurance and pension funding (64)
5% Wholesale trade, except in motor vehicles and motorcycles (46)	4% Construction of buildings (41)	3% Publishing activities (58)
4% Human health activities (86)	4% Wholesale trade, except in motor vehicles and motorcycles (46)	3% Wholesale trade, except in motor vehicles and motorcycles (46)
3% Activities of head offices; Management consultancy activities (70)	3% Manufacture of motor vehicles, trailers and semi-trailers (29)	3% Telecommunications (61)
2% Social work activities without accommodation (88)	3% Retail trade, except in motor vehicles and motorcycles (47)	2% Manufacture of computer, electronic and optical products (26)
2% Computer programming, consultancy and related activities (62)	3% Computer programming, consultancy and related activities (62)	2% Information service activities (63)
Total: 20 080 000	Total: 11 693 000	Total: 2 180 000

Physical sciences (including physics, chemistry and earth science)	Life sciences (including biology and environmental sciences)	Mathematics and statistics
21% Education (85)	24% Education (85)	38% Education (85)
9% Public administration and defence; Social security (84)	11% Human health activities (86)	10% Computer programming, consultancy and related activities (62)
7% Scientific research and development (72)	9% Public administration and defence; Social security (84)	7% Public administration and defence; Social security (84)
5% Architecture and engineering; Technical testing & analysis (71)	9% Scientific research and development (72)	4% Financial service activities, except insurance and pension funding (64)
4% Manufacture of chemicals and chemical products (20)	7% Retail trade, except in motor vehicles and motorcycles (47)	3% Insurance, reinsurance and pension funding (65)
4% Retail trade, except in motor vehicles and motorcycles (47)	5% Manufacture of basic pharmaceutical products and preparations (21)	3% Retail trade, except in motor vehicles and motorcycles (47)
4% Computer programming, consultancy and related activities (62)	3% Wholesale trade, except in motor vehicles and motorcycles (46)	3% Activities of head offices; Management consultancy activities (70)
3% Manufacture of basic pharmaceutical products and preparations (21)	2% Architectural and engineering activities; Technical testing & analysis (71)	3% Activities auxiliary to financial services and insurance activities (66)
3% Wholesale trade, except in motor vehicles and motorcycles (46)	2% Activities of head offices; Management consultancy activities (70)	2% Legal and accounting activities (69)
2% Human health activities (86)	2% Computer programming, consultancy and related activities (62)	2% Publishing activities (58)
Total: 1 501 000	Total: 1 118 000	Total: 562 000

Note: Percentages stand for the shares of graduates in each specific discipline working in each specific sector. The numbers in parentheses correspond to the economic activity according to the NACE Rev.2 (2-digit level) classification. Totals are rounded numbers. Fields of science correspond to the ISCED classification of 1997.

Source: European Union Labour Force Survey, 2013.

[1] One survey that allows for such identification is the School Basic Survey in Japan – a university (cohort) graduate survey. Yet this survey has limitations in terms of data granularity, as it only identifies 11 disciplines and industries at the 1-digit level of JSIC.

[2] More detailed information at the country level is provided in an online statistical annex that presents information on the industry destination of graduates in specific academic fields for the 32 countries covered by the European Union Labour Force Survey (EU-LFS). The annex can be accessed at www.oecd.org/sti/inno/what-role-for-social-sciences-in-innovation-statistical-annex.pdf.

[3] The two surveys gather information about graduates five years after qualifying for the higher education level degree, on the basis of representative samples of tertiary graduates. They cover the following countries: Austria, Belgium, Czech Republic, Estonia, Finland, France, Germany, Hungary, Italy, Japan, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Switzerland, Turkey and the United Kingdom. For more information: www.hegesco.org/ and http://roa.sbe.maastrichtuniversity.nl/?portfolio=reflex-international-survey-higher-education-graduates.

[4] The definition of ICT sectors is based on OECD, 2007 and UNCTAD, 2015. For more details on the classification of activities included as ICT sectors, see Paunov, Planes-Satorra and Moriguchi, 2017.

[5] Data refer to the UK labour force with tertiary education that gained bachelor's degrees (and possibly higher-level degrees) in the United Kingdom. Excluded therefore is the labour force that gained bachelor's degrees abroad, even if those persons undertook higher-level degrees in the United Kingdom. Data do not include combined subject degrees, but only focus on single subject degrees.

Part II. Policy instruments and the policy mix for science-industry knowledge transfer

Part II of this report consists of three chapters. Chapter 4 introduces a new taxonomy of policy instruments to support knowledge transfer between science and industry, and discusses their positive and negative interactions. Chapter 5 explores in particular the policy mix in support of spin-offs, based on a set of case studies. Chapter 6 presents new evidence on governance of public research supporting knowledge transfer, pointing to the greater autonomy of universities and PRIs in engaging in knowledge transfer and the importance of governance for the effectiveness of the policy mix for knowledge transfer.

Chapter 4. Policy instruments and policy mixes for knowledge transfer

This chapter introduces a new taxonomy of 21 policy instruments to support knowledge transfer between science and industry, which can be classified into financial, regulatory or soft instruments, and characterised by their target, the channels they address and their supply- or demand-side orientation. The chapter also discusses the role of intermediary institutions in policy design, and then analyses differences in the policy mix across countries and examines interactions among policy instruments. It concludes by discussing key trends that characterise the recent evolution of knowledge transfer policies in OECD countries.

Introduction

OECD countries use various policy instruments to stimulate science-industry knowledge transfer. Examples include grants for collaborative university-industry research, tax incentives for firms that purchase services from universities, financial support to university spin-offs, mobility schemes for researchers and networking events, among others. The impacts of single instruments depend not only on the features of the instrument but also on other instruments in place. For instance, grant programmes to support collaborative research work better when accompanied by networking services and guidelines for IP management. Yet, the prevalent approach in policy analysis has been to evaluate instruments in isolation, providing little insights on the policy mix.

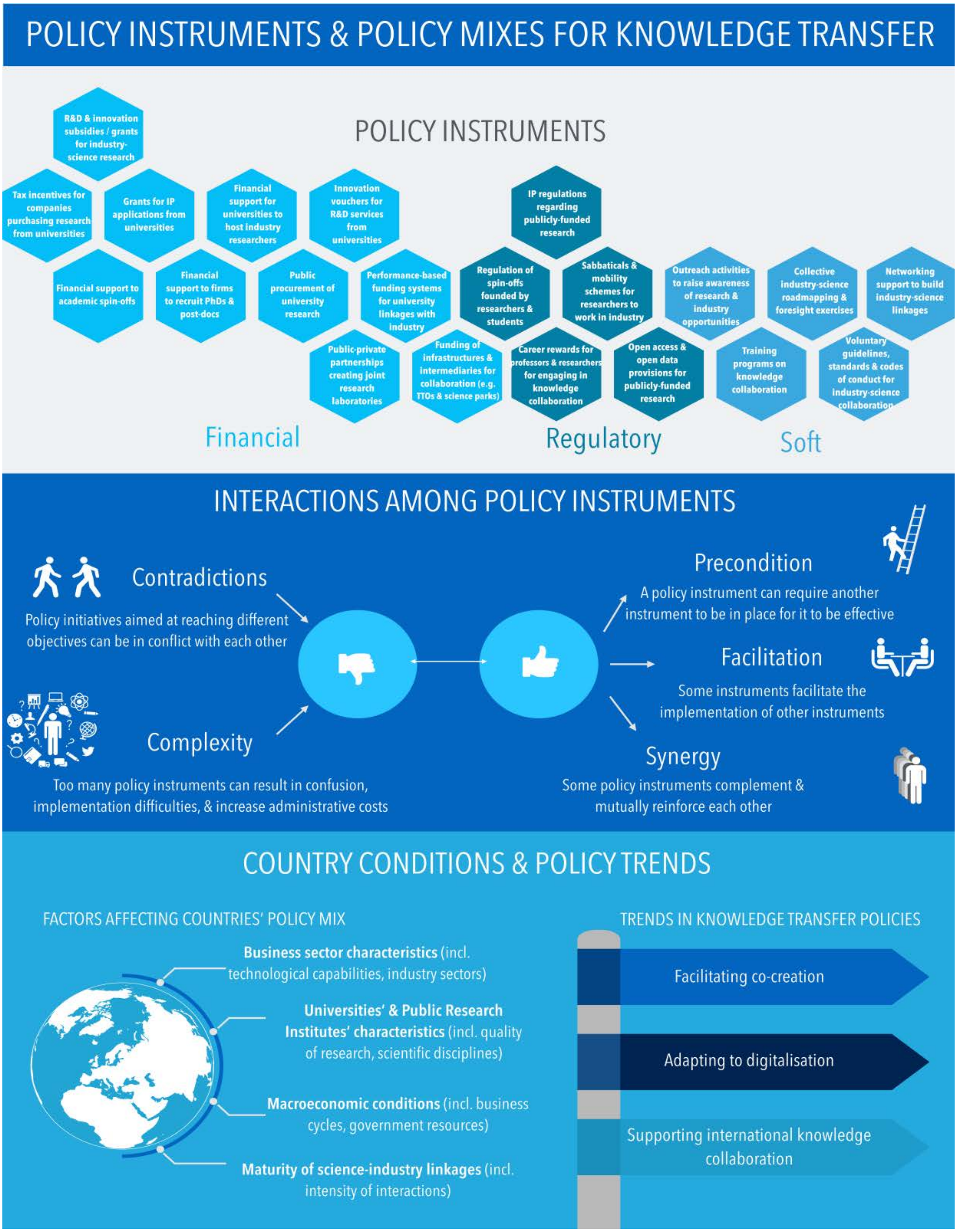
This chapter provides a comprehensive overview of the policy instruments used to support knowledge transfer and different possible categorisations of these policies. It also discusses the interactions between policy instruments and how the policy mix has changed over time. Since policies to promote knowledge transfer are a subset of a country's overall science, technology and innovation (STI) policies, the broader innovation, economic and social policies are also taken into consideration.

The chapter identifies 21 policy instruments, which can be classified by: i) whether they are financial, regulatory or soft instruments; ii) whether they target primarily firms/industry, researchers or universities/public research institutes (PRIs); iii) the type of knowledge transfer channels being addressed; and iv) the supply- or demand-side orientation of policy instruments. While OECD countries tend to use the same type of policy instruments, differences across countries appear in the relative importance accorded each type of policy (e.g. in terms of budget or number of initiatives) and in the detailed design or implementation of the policy instrument (e.g. in terms of target groups, eligibility criteria, time horizon, etc.).

In addition to the composition of the policy mix, the interactions (both positive and negative) among its elements are critical to outcomes. This means that a country's choice of financial, regulatory and soft instruments to promote knowledge transfer needs to be coherently aligned, so that the different policy instruments reinforce and complement each other rather than resulting in contradiction, confusion or excessive complexity. Potential interactions with broader economic and social policies also need consideration. For example, labour market policies influence the mobility of researchers, which is an important channel of knowledge transfer.

Changes in policy mix over time reflect policy learning and respond to new demands on industry-science knowledge transfer. Recent trends include i) a shift from a linear model of knowledge transfer towards an interactive model of knowledge co-creation; and ii) new policy approaches in response to digitalisation and globalisation.

Figure 4.1. Synthesis of chapter 4



Policy initiatives aimed at reaching different objectives can be in conflict with each other

Too many policy instruments can result in confusion, implementation difficulties, & increase administrative costs

A policy instrument can require another instrument to be in place for it to be effective

Some instruments facilitate the implementation of other instruments

Some policy instruments complement & mutually reinforce each other

The following conclusions can be drawn regarding setting policy mixes for knowledge transfer:

- Given the diversity of channels through which knowledge transfer unfolds, various policy instruments targeting alternative channels need to be adopted to avoid focusing only on channels relevant to specific sectors, disciplines, or actors.
- Systematically assessing combined effects of instruments, as well as potential redundancies, contradictions and remaining problems that could be addressed with new instruments, can help improve the policy mix.
- A country's policy mix should reflect its specific structural and institutional characteristics, including its level of socio-economic development, macroeconomic conditions, R&D intensity, industrial specialisation, and characteristics of universities and PRIs, among other factors.

The remainder of the chapter is structured as follows. Section 4.1 describes the policy instruments in place to support science-industry knowledge transfer across OECD countries, while section 4.2 discusses the intermediary institutions set up to help support implementation of those policy instruments. Section 4.3 analyses differences in the policy mix across countries. Section 4.4 focuses on assessing the interactions among policy instruments. Section 4.5 discusses key trends that characterise the recent evolution of knowledge transfer policies in OECD countries. Finally, Section 4.6 provides concluding remarks.

4.1. What policy instruments are in place to promote knowledge transfer?

Table 4.1 presents the main policy instruments used across OECD countries to support industry-science knowledge transfer, classified into three broad categories:

- *Financial instruments* include different kinds of economic transfers from the state to firms, universities or PRIs, conditional on their collaboration among each other.
- *Regulatory instruments* aim at providing incentives to the different parties involved in science-industry knowledge transfer, including laws affecting the careers of researchers, the funding of universities, or the ownership of patent rights.
- *"Soft" instruments* include less interventionist modes of public policy focused on facilitating relationships, mobilising, networking, integrating and building trust.

Policy instruments differ in several other respects as well: the target groups, the main channel of knowledge transfer addressed, and whether the policy is a supply- or demand-side oriented instrument. Given the diversity of channels through which knowledge transfer unfolds, it would appear important to use various policy instruments targeting alternative channels, rather than focusing only on the more traditional, measurable channels such as patent licensing or spin-off creation. There should also be a sound mix of policies to address the barriers faced by the different target groups involved, including firms, universities/PRIs and individual researchers. Some studies also highlight the importance of combining demand- and supply-side measures (Guerzoni and Raiteri, 2015).

Table 4.1. **A taxonomy of policy instruments to support knowledge transfer**

Type of policy instrument	Brief description	Target groups	Main channels	Supply vs. demand
Financial instruments				
1. R&D and innovation subsidies or grants	Direct financing of collaborative projects, ranging from generic to mission-oriented calls, and from small-scale, challenge-driven competitions to large consortia.	Researchers, universities/PRIs and firms	Collaboration	Supply
2. Tax incentives	Tax credits (i.e. indirect financial instruments) for companies that engage in collaborative research or purchase services from universities/PRIs.	Firms	Collaboration, contracts, consulting	Supply
3. Financial support to academic spin-offs	Including proof-of-concept, seed funds, business plan competitions, public venture capital, etc.	Researchers and entrepreneurs	Spin-offs	Supply
4. Grants for IP applications	Covering the costs of registration in patent offices, to encourage researchers to disclose and commercialise their inventions.	Researchers	IP licensing	Supply
5. Financial support to recruit PhDs or post-docs	Financial support to firms that recruit PhDs or post-docs, covering part of the salary.	Firms	Researchers' mobility	Supply
6. Financial support to host industry researchers	Financial support schemes for universities to host industry researchers temporarily.	Universities/PRIs	Researchers' mobility	Supply
7. Public procurement	Sourcing of goods and services by public authorities from universities or PRIs	Firms	Collaboration, contracts	Demand
8. Innovation vouchers	Small financial support for firms (especially SMEs) to purchase R&D services from certified researchers from universities/PRIs.	Firms	Contracts, consulting	Demand
9. Public-private partnerships creating joint research laboratories	To create joint research centres co-funded by the public sector and a company. Sometimes called collaborative, co-created, or competence centres.	Universities/PRIs and firms	Collaboration	Demand/ Supply
10. Performance-based funding systems	To reward linkages with industry, e.g. providing earmarked funding based on number of contracts with industry, IP licences, spin-offs, etc.	Universities/PRIs	Publications, spin-offs, IP licensing	Supply
11. Funding of infrastructures and intermediaries	Including technology transfer offices (TTOs), science parks, business incubators.	Universities/PRIs	IP licensing, spin-offs, collaboration, networking	Demand/ Supply

Regulatory instruments				
12. IP rights regime	Ownership of IP resulting from public-private research. Allocation of IP revenue from publicly funded research.	Researchers, firms and universities/PRIs	IP licensing, spin-offs	Demand/ Supply
13. Regulation of spin-offs founded by researchers and students	Conditions for university's involvement as shareholder, distribution of revenue, implications for academics' salaries, contractual possibilities for university staff to participate in spin-offs, etc.	Researchers and universities/PRIs	Spin-offs	Supply
14. Career rewards for professors and researchers	Rewards for mobilising private research funds, earning income from IP licensing, creating spin-offs. Regulations can also facilitate industry-financed chairs, as well as part-time positions for practitioners.	Researchers	All channels	Supply
15. Sabbaticals and mobility schemes	Regulations allowing sabbaticals for scientists to join industry and temporary recruitment of industry researchers.	Researchers and universities/PRIs	Researchers' mobility, spin-offs	Supply
16. Open access and open data provisions	Requirements to publish in open access results of publicly funded research openly and to make the data available.	Researchers and universities/PRIs	Publications	Supply
Soft instruments				
17. Awareness-raising	Outreach activities to raise awareness, including information brochures and websites, conferences and seminars.	Universities/PRIs and firms	All channels	Demand/ Supply
18. Training programmes	Training delivered by government agencies covering different aspects of knowledge transfer.	Researchers, TTO staff	All channels	Supply
19. Networking	Events, workshops, and fairs where firms can express their technology needs and scientists can present the results of their research.	Universities/PRIs and firms	Networking	Demand/ Supply
20. Collective roadmapping and foresight exercises	Initiatives bringing together actors from business and academia to identify technological opportunities and priorities for future research.	Universities/PRIs and firms	Networking	Demand/ Supply
21. Voluntary guidelines, standards and codes of conduct	Guidelines for the management of IP developed through collaborative projects; sample contracts for collaborative research; etc.	Universities/PRIs and firms	Collaboration, IP licensing	Demand/ Supply

Other relevant attributes to consider when evaluating policy instruments are their stability – i.e. actors can rely on the instrument being available to them as specified; flexibility, i.e. there are possibilities to adapt to specific cases where justified; and operational characteristics, i.e. the characteristics of the policy instrument process.

4.2. Intermediary organisations

Over the past decades, OECD countries have developed a complex network of intermediary organisations to implement knowledge transfer policies, such as innovation agencies, technology transfer offices (TTOs) and business incubators (OECD, 2013). Intermediary organisations differ in their size, mission, activities, ownership and funding structure. Some intermediary organisations are autonomous agencies tasked with promoting knowledge transfer and innovation more generally. Others are established as units of a specific university, as is often the case with TTOs and science parks.

In particular, a growing number of TTOs have been developed across OECD countries since the mid-1990s to support different stages of the commercialisation cycle such as patent applications, invention disclosures, pilots and prototypes, establishing spin-off companies, contracts with industry, identifying business needs, searching for partners and funding sources, etc. More recently, some countries have developed new types of regional or sectoral TTOs based on an association of several institutions that pool services to improve efficiency and quality, to complement the traditional approach of individual TTOs at each university. The recent experiences of Chile, Colombia and France are useful to illustrate this trend:

- In France, a total of 14 "technology transfer acceleration companies" (SATTs) have been created since 2011 to co-ordinate the TTOs of universities/PRIs within regions. They have pooled certain functions of their member organisations (e.g. IP management) and developed new activities (e.g. technology development).
- In Colombia, six regional TTOs have been created since 2013 through alliances among universities, research institutes and firms, in order to build sufficient critical mass to operate more efficiently and to be able to provide high-quality specialist services. This is discussed in detail in a case study developed by Colombia for this project (Botero-Ospina, Sánchez Salazar and Pontón-Silva, 2019).
- Chile opted for a sectoral approach whereby three "Technology transfer hubs" were created in priority sectors (agriculture, health, and industrial production and energy), as decentralised entities whose shareholders are a group of at least six universities/PRIs. Hubs complement individual TTOs of participating universities, e.g. by centralising some functions such as international commercialisation of technologies. This model is explained in detail in a case study developed by Chile for this project (Ministry of Economy, Development and Tourism of Chile, 2019).

Other countries have recently created new intermediary organisations specialising in the needs of SMEs. The following are two examples:

- The Canadian Technology Access Centres (TAC) grant programme focuses on enhancing the innovative capacity of SMEs through collaborative access to specialised talent, expertise, equipment and technology from Canadian colleges. The programme delivers financial support to a network of 30 TACs throughout the country, which are small specialised applied R&D centres affiliated with a Canadian college that receive a five-year renewable grant. This programme is discussed in detail in the case study developed for this project (Innovation, Science and Economic Development Canada, 2019).
- The Patent Commercialisation Platform (PCP) in Korea connects researchers from 24 universities and more than 8 000 SMEs. The PCP employs experts that provide advice to SMEs and match SMEs with university technologies to support technology transfer. The PCP also offers follow-up financing for commercialisation of these technologies by SMEs.

The digital transformation is also affecting intermediary organisations. New digital platforms – Internet-based structures that organise interaction among different actors – facilitate the matchmaking between academic and industry partners, complementing the role of TTOs. Public research and universities can advertise their inventions, knowledge and capacities, and businesses can post their particular needs. The two sides can then interact and agree on deals. Such platforms support in particular small-scale entrepreneurs, by offering opportunities to identify adequate niche markets. For example, *Expert Connect* is a searchable database created by Data61 in Australia that contains profiles of more than 45 000 research and engineering experts from Australian research organisations (Data61, 2018).

4.3. How countries differ in their policies to support knowledge transfer

The types of instruments used across countries are usually very similar. This convergence may be due to peer learning and "policy diffusion", including policy recommendations by international organisations and information exchange among countries (Knill, 2005). However, as stated above there are significant differences across countries in the relative importance accorded each type of policy (e.g. in terms of budget or number of initiatives) and in the detailed design or implementation of the policy instrument (e.g. in terms of target groups, eligibility criteria, time horizon, etc.).

A recent comparative study of the knowledge transfer policy mix used in eight countries (Sanz and Cruz-Castro, forthcoming) confirms, based on the EC-OECD STIP Compass database, that there are differences in the relative importance of policy instruments The countries analysed are Austria, Canada, France, Hungary, the Netherlands, Norway, Portugal and Spain, while the policy instruments are classified into five types: Direct financial support; Indirect financial support; Guidance, regulation and other; Collaborative; and Governance. The study finds that direct financial support is the dominant type of initiative in Austria, Hungary and Norway. The Netherlands and, to a lesser extent, Canada have greater shares of governance initiatives, compared with the other countries. France has a uses a mix of all these policy instruments. The authors validate their findings based on qualitative interviews they held with country stakeholders.

There are also large differences in how different countries implement each type of policy instrument. For example, competitive grant programmes to fund collaborative R&D projects have become widely used across OECD countries, but a large variety appears in terms of their budget, grant duration, direct beneficiaries, selection criteria and eligible activities (Table 4.2). The most common approach is to offer a maximum grant of more than EUR 1 million (40% of cases) over 25-36 months (75%), but some countries offer lower grants over a shorter period.

When it comes to promoting the industry-academia mobility of researchers, some countries focus on mobility from firms to universities, others from universities to firms, and others still on both simultaneously (Table 4.3). Some programmes offer financial subsidies. Among those providing financial subsidies, the proportion of the salary subsidised and the average duration of the subsidy also differ. Other programmes provide mainly guidelines and networking services.

Table 4.2. **Grant programmes for public research requiring collaboration with industry partners**

129 policy initiatives from 34 countries in 2017[1]

Descriptive statistics	
Maximum amount of grant awarded, EUR	
Less than 100K	14%
100K-500K	31%
500K-1M	15%
More than 1M	40%
Annual budget range, EUR[2]	
Less than 1M	10%
1M-5M	21%
5M-20M	17%
20M-50M	19%
50M-100M	8%
100M-500M	10%
More than 500M	15%
Maximum grant duration	
12 months or less	6%
13-24 months	19%
25-36 months	75%
Direct beneficiaries[3]	
Established researchers	44%
Undergraduate/master's students	14%
Post-doctoral researchers	28%
PhD students	33%
Higher education institutes	57%
Public research institutes	53%
Type of activities funded[3]	
Basic research	46%
Applied research	92%
Experimental development	37%
Selection criteria[3]	
Scientific impact anticipated	65%
Commercial impact anticipated	57%
Track record of applicant	53%
Societal impact anticipated	43%
Alignment with national priorities	36%
Social inclusion in research	8%
Geographical location	7%

Notes:

[1] The 34 countries in the sample are Australia, Austria, Belgium, Bulgaria, Brazil, Canada, Chile, China, Colombia, Costa Rica, Czech Republic, Germany, Finland, France, Greece, Hungary, Ireland, Latvia, Lithuania, Malta, Mexico, Morocco, the Netherlands, Norway, Peru, Poland, Portugal, Russia, Slovenia, Sweden, Switzerland, Thailand, Turkey and the United Kingdom.

[2] For this question only, the sample size is 103 because 26 observations with the answer missing are excluded.

[3] Notice that the sums are not 100%; this is because each initiative may have several different beneficiaries, eligibility criteria and type of activities funded.

Source: STIP Compass database.

Table 4.3. **Policy initiatives to promote mobility of researchers: Selected examples**

Country	Name of initiative	Mechanisms			Share of salary subsidised	Average duration of subsidy	Mobility destination	
		Guidelines and information	Financial subsidy	Networking			HEIs or PRIs	Private firms
Canada	Mitacs - Elevate	Yes	Yes	Yes	>80%	>18 months	No	Yes
Colombia	Integration of PhDs into Colombian companies	No	Yes	No	>80%	>18 months	No	Yes
France	Vade-Mecum of Public-Private Linkages	Yes	No	No	-	-	No	Yes
Korea	3rd Basic Plan for Nurturing S&T Human Resources	Yes	No	Yes	-	-	Yes	Yes
Norway	Research-Based Regional Innovation	No	Yes	No	40-80%	6-18 months	Yes	Yes
Peru	Article 86 of the University Law 30220	No	Yes	No	40-80%	6-18 months	Yes	No
Thailand	Talent Mobility	No	Yes	Yes	>80%	6-18 months	No	Yes
United Kingdom	CASE Studentships	No	No	Yes	-	-	Yes	Yes

Note: HEIs = higher education institutions; PRIs = public research institutes.
Source: STIP Compass database (retrieved in July 2018), considering only policy initiatives active in 2017.

Several OECD countries also offer innovation vouchers to promote contract research and academic consultancy, but the design of such vouchers varies largely (e.g. in terms of voucher amount and eligibility criteria) (**Table 4.4**). Many focus on providing innovation vouchers to SMEs, on the condition that they use it to contract services from a certified knowledge provider from a university or PRI.

Table 4.4. **Examples of innovation voucher programmes that support the acquisition by firms of specialised services from universities and PRIs**

Country	Name of initiative	Estimated budget range per year, EUR	Voucher amount, EUR	Eligibility criteria		
				Firm size (SMEs or start-ups)	Firm receives no other public aid for innovation	Knowledge provider is certified
Austria	Innovation Voucher	1-5 million	<10 000	Yes	No	No
Australia	Innovation Vouchers Programme	Missing answer	2 000 - 6 000	Yes	No	No
Chile	Innovation Vouchers	1-5 million	6 000 - 10 000	No	No	No
Czech Republic	Innovation Vouchers	Missing answer	varies	Yes	No	Yes
Estonia	Innovation Voucher	<1 million	2 000 - 6 000	Yes	Yes	Yes
Estonia	Development Voucher	1-5 million	varies	Yes	Yes	Yes
Hungary	Innovation Voucher	<1 million	<16 000	Yes	No	Yes
Korea	R&D Voucher System	5-20 million	6 000 - 10 000	Yes	No	Yes
Lithuania	Innovation Vouchers	1-5 million	2 000 - 6 000	No	Yes	Yes
Netherlands	SME Innovation Support Top Sectors	20-50 million	2 000 - 6 000	Yes	Yes	Yes
Portugal	Innovation Voucher	5-20 million	varies	Yes	Yes	Yes
Russia	Innovation Vouchers for Enterprises	50-100 million	varies	No	No	No
Switzerland	Innovation Cheque	<1 million	<2 000	No	No	No
Turkey	Techno-preneurship Support Programme	1-5 million	varies	Yes	No	No

Source: EC-OECD STIP Compass database (retrieved in July 2018), considering only policy initiatives active in 2017.

These examples help illustrate the variation that appears across countries, reflecting different policy "implementation styles" (Howlett, 2004). Such divergence may be well justified and reflect the specific country context in which they are applied, including the country's level of socio-economic development, size, R&D intensity, and other structural and institutional factors. In particular, the following factors matter:

a) The *characteristics of the country's business sector*, including firms' size, sector of activity, technological capabilities, and ownership structure. For example, informal channels of knowledge transfer (e.g. networking, facility sharing, on-the-job training, etc.) are often very important for those SMEs with limited capabilities to engage in more formal channels of collaboration. Moreover, high-, medium- and low-technology sectors behave very differently with respect to knowledge transfer, and require different kinds of incentives. For instance, low-technology sectors often have fewer linkages with universities and also less staff with a science background; that requires more efforts to establish linkages with industry, to start a process of collaboration between the industry and universities.

b) The *characteristics of universities and PRIs*, including their level of investment in research, orientation towards basic or applied science, the quality of the research they conduct, and the incentives they set for researchers. For example, smaller and less research-intensive universities often rely on different channels for knowledge transfer, focusing less on patent transactions or joint research projects and more on student entrepreneurship and informal networking. Governments should be sensitive to this heterogeneity when evaluating their policy mix to support knowledge transfer.

c) Countries' *macroeconomic conditions,* as these influence the public resources available, the broad strategies of private firms, and the mobility of researchers. For example, countries suffering economic recessions often face challenges that affect knowledge transfer directly, such as the emigration of highly skilled researchers and the cuts of state support to innovation due to financial austerity measures.

d) The *maturity of science-industry linkages* resulting from historic practice. For example, innovation vouchers can be a very good way to build initial connections where the latter are non-existent, but in the longer term may prove not to be the best tools to deepen industry-science linkages. Other methods aimed at promoting co-creation will at this point become more effective.

In view of these differences in country conditions, the same types of instruments with the same characteristics are not suitable in all cases, and a more diversified approach is needed. Better understanding of what these country conditions are would in turn improve understanding of the ways best practice examples that are effective in one country can be applied in another.

4.4. Assessing interaction dynamics within the policy mix

Policy instruments are not implemented in isolation. Hence, aside from adopting effective individual policies, the potential interactions among policy instruments are critical to outcomes. As outlined in Table 4.5, different kinds of positive and negative interactions may arise when policy instruments are combined in a policy mix.

Precondition effects imply that, besides the combination of policy instruments, it is also important to consider the sequence whereby they are introduced. A certain regulatory change may be necessary to ensure the impact of a new grant programme to support academic spin-offs; or perhaps a training programme is necessary before creating new technology transfer offices at universities. Similarly, governments of OECD countries are increasingly aware of the importance of soft policy instruments given their *facilitation* effect over other financial and regulatory instruments to support knowledge transfer. For instance, several countries have complemented Bayh-Dole-type regulatory frameworks on the ownership of IP rights generated from publicly funded research, and the distribution of revenues from commercialisation, with "soft instruments" to facilitate implementation. A *synergy* will occur when two policy instruments complement and mutually reinforce each other. This may be the case with different grant programmes that offer funding for different activities or focus on different stages of the commercialisation cycle.

Negative interactions between policy instruments for knowledge transfer also need consideration. For example, there might be a *contradiction* between policy initiatives that respond to different rationales or that aim to target alternative channels to knowledge transfer. In addition, negative interactions can derive from the *complexity* of using too many policy instruments simultaneously. This may be the result of inefficient co-ordination of national and regional governments, leading to inconsistencies, bureaucratic and political conflict, and lack of consensus when setting priorities. It may also simply reflect the "policy layering" process whereby new policy programmes tend to be piled on top of one another, sometimes as a result of sequential changes in government.

Table 4.5. **Types of interactions among policy instruments**

Type of interactions	Description	Example
Positive interactions		
Precondition	X is necessary in order to implement Y (i.e. the sequence by which policy instruments are introduced matters).	The case study of Colombia (Botero Ospina, Sánchez Salazar and Pontón Silva, 2018) shows how, following the introduction of new grants for spin-offs in 2010, it was later deemed necessary to remove regulatory barriers that impeded employees of public universities and research institutes from creating a new company or holding a second post; this led to the enactment of a new law in 2017.
Facilitation	X increases the effectiveness of Y, but Y has no impact on X.	In 2015 the Japanese Government launched the "Guidelines for IP management in government-commissioned research and development" to facilitate implementation of the Japanese version of the Bayh-Doyle Act dating back to 1999.
Synergy	X increases the effectiveness of Y, and vice versa.	The Small Business Innovation Research (SBIR) programme, implemented by the US Federal Government since 1982, has benefited substantially from complementary outreach programmes and matching grants offered at the US state level (Lanahan and Feldman, 2015).
Negative interactions		
Contradiction	X decreases the effectiveness of Y, and vice versa.	New policy approaches aimed at promoting knowledge sharing through open access, open data, open software, etc. may be in contradiction with more traditional policies aimed at protecting IP rights (Herstad et al., 2010).
Complexity	Using too many policy instruments results in confusion for target groups, operational difficulties, and increased administrative costs for the government.	In view of the vast and complicated array of programmes in place to support business innovation, in 2018 the government of Canada announced a major reform aimed at simplifying the policy mix by making it easier to navigate and more adapted to the needs of target firms. As a result, total overall funding for business innovation programming will increase, but the total number of business innovation programmes (currently 92) will be reduced by up to two-thirds.

The case study from Greece offers an interesting example of the importance of considering negative interactions among policy instruments (Spilioti, Gongolidis and Gypakis, 2019). In 2017, at the time of launching a new public venture capital fund to promote spin-offs in Greece, concerns were expressed about the potential overlap with a programme providing direct grants for spin-offs, which had been in place since 2001. As a result, it was decided to fine-tune the eligibility criteria so that the grant programme would focus on the earlier stages, and to delay the next call of the grant programme until the first results of the venture capital fund would be available.

4.5. Current trends and emerging policy approaches

This section explores how policy learning and new demands on industry-science knowledge transfer shape the evolution of knowledge transfer policies over time. The case study produced by Finland within this project (Halme et al., 2019) illustrates nicely the dynamic nature of the policy mix. Policies in Finland aimed at enhancing industry-science linkages evolved from a more supply-driven approach towards one with a stronger focus on developing competencies and incentives for demand or user-driven innovation activity, promoting public-private partnerships, increasing citizens' participation opportunities, and developing new co-operating models and platforms. There has also been a shift from research-driven policies focused on big companies towards more innovation-driven, start-up-focused approaches.

Likewise, the case study of Austria provides a comprehensive analysis of how the country's policy mix has evolved in recent years to better address the barriers that hamper technology transfer (Ecker, Reiner and Gogola, 2019). The most recent developments include the Spin-off Fellowships programme and the new incubator IST Cube, both launched in 2017 with the aim of further promoting start-up activities of researchers; the IP Hub online platform, created in 2017 as a one-stop-shop for IP rights; and new funding instruments to develop individual strategic projects in co-operation with industry, such as the Silicon Austria Labs – a newly created research facility bringing together industry and science for electronic-based systems with a long-term perspective. Various policy instruments have been used to support long-term science-industry co-operation, research excellence and frontier application-oriented basic research. Relevant examples include the COMET programme, to establish competence centres at the interface of industry and academia, and the Christian Doppler Research Association, to fund industry-relevant fundamental research at universities. This reflects a shift in the policy mix towards more emphasis on co-creation. Moreover, the policy mix to support knowledge transfer in Austria has benefited from a "bottom-up" approach to ensure that policies were well aligned with the specific characteristics of the country's companies and academic institutions.

More broadly, the following trends – described below – can be observed in the policy mix of OECD countries:

- First, policy makers are increasingly supporting new modes of science-industry co-creation that push the boundaries of traditional linear models of knowledge transfer.
- Second, as digitalisation continues to advance, policies for knowledge transfer are adapting to this new context.
- Third, knowledge transfer policies are increasingly adopting a broader international dimension.

New approaches towards knowledge co-creation

The concept of science-industry knowledge transfer has often been contested on the grounds that it suggests unidirectional and linear flows, while in reality these are two-way and interactive relations. Indeed, "co-creation" (rather than simple transfer) of knowledge by firms and research institutions is critical to allow innovation ecosystems to optimally benefit from scientific research. Co-creation means that more intense science-industry relations are built as knowledge is developed jointly through shared facilities and mixed teams. The direct involvement of government and civil society is also a characteristic of a number of ambitious knowledge co-creation structures. The success of such multi-stakeholder co-creation processes requires experimenting with new physical and virtual ways to collaborate.

Besides strategic long-term research partnerships, co-creation may involve other knowledge transfer channels, such as the mobility of human capital. This entails building conditions allowing for two-way, "revolving door" mobility for university and PRI researchers to temporarily join industry and for industry researchers to temporarily participate in university activities. Some mechanisms to achieve this include industrial PhD programmes based on joint supervision and co-financing; sabbatical periods for professors; professional secondments for university professors; and adjunct professorships for industry professionals.

Examples of how several OECD countries have supported the development of joint research laboratories and public-private partnerships for co-creation include the following:

- The Catapult centres, launched in 2015, bring together businesses, scientists and engineers to work on late-stage R&D in strategic fields. To date, ten Catapults have been established, each specialising in different industries/technologies; physical centres are spread across the United Kingdom with different working modes (MacAulay, 2017).
- Collaborative laboratories in Portugal (CoLAB), launched in 2018, are private, non-profit foundations or private companies that integrate activities of research units of higher education institutions, public research laboratories, intermediate organisations, companies and business associations (Encarnação, 2017). With a high share of private funding (>50%), they focus on performing market-driven research and providing professional R&D services to industry.
- The French LabCom programme was launched in 2013 to support the establishment of joint labs for universities/PRIs and firms (with a particular focus on SMEs). Selected projects are awarded up to EUR 300 000 for maximum duration of 36 months.
- The Austrian Christian Doppler (CDG) Laboratories are established based on an industry challenge (industry-relevant questions in basic research), receive 50% of industry co-funding, and last no longer than seven years. The CDG programme represents a more flexible approach than the previous examples because it does not establish new legal entities, as CDG laboratories are hosted at universities (Harms, 2018).
- In Hungary, the Centres for Higher Education and Industrial Cooperation (FIEK) programme was launched in 2017 to encourage new organisational models for long-term university-industry links. The centres are established within the premises of universities, as autonomous organisational units under the direct control of the rector, to enhance their flexibility and reduce bureaucracy (Hungarian National Research, Development and Innovation Office, 2019).

Adapting knowledge transfer policies to digitalisation

The digital transformation is progressively making innovation ecosystems open and diverse. Firms increasingly engage in interactions with research institutions and other firms for three main reasons. First, this allows them to gain access and exposure to a richer pool of expertise and skills that are complementary to their own competencies (e.g. data analytics). Access to such talent is critical, as innovation in the digital age is complex and requires new mixes of skills. Second, such collaborations allow sharing the costs and risks of uncertain investments in digital innovation. Firms often face several potential research and technology development paths, mastery of which requires large-scale investments with uncertain outcomes. Engaging with others is a way to expand into different areas while collectively sharing costs. Third, reduced costs of communication allow densified interactions among actors engaged in innovation (e.g. firms, public research institutions), regardless of their location.

Collaborations take different forms, as explored in more detail in the final report of the OECD-TIP *Digital and Open Innovation* project (OECD, forthcoming). Most innovative approaches to open innovation, enabled by digital technologies, include online communities of experts, tournaments, open calls and crowdsourcing.

Digital platforms such as InnoCentive, IdeaConnection or Presans, to name a few, help to match supply and demand for technology by connecting firms with global networks of public research centres, individual scientists and freelancers to solve specific technological problems. Such platforms benefit from network effects, as they are able to reach to a wide range of experts across the world. In other cases, firms create their own platforms, sometimes managed by companies such as Yet2. Several governments and universities have also built open innovation platforms. For example, Citizenscience.gov is an initiative designed by the US Government to accelerate the use of crowdsourcing so as to engage the public in addressing social needs and accelerate innovation.

Digital platforms play an increasingly relevant role in disclosing technology and creating opportunities for universities and firms to identify potential partners, thereby increasing transparency and substantially reducing transaction costs. In addition, research results and data are becoming more easily (and freely) available through open data and open access practices, while the interactions of science and civil society are being enhanced through open science. These developments are influencing the mechanisms for science-industry knowledge transfer and call for new policy approaches. At the same time, physical spaces and intermediaries often remain critical, with digital platforms complementing but not replacing human interactions.

Policies to support knowledge transfer across borders

Knowledge transfer policies across OECD countries are embracing a stronger international scope – to connect with global innovation networks and build the necessary critical mass to deal with grand societal challenges such as climate change. For instance, in Japan the Science and Technology Research Partnership for Sustainable Development (SATREPS) provides grants to enhance co-operation in science and technology between Japan and developing countries; the objective is to develop new knowledge and technologies that will help address global issues, such as climate change, disaster prevention and public health. At EU level, the Joint Programming Initiatives (JPIs) aim to pool research efforts of EU members with the objective of tackling grand challenges (European Commission, 2019).

In addition, new policy approaches are emerging that benefit from the spread of global innovation networks. In particular, governments are increasingly aware of the importance of attracting multinationals' R&D centres, and for this purpose policies to support knowledge transfer should adopt a broad scope to ensure that the ecosystem is attractive not only for local players but also for foreign multinational enterprises. Some countries have also recently launched dedicated programmes to attract international universities and PRIs to establish new research centres locally in collaboration with national universities and firms. Examples include the Campus for Research Excellence and Technological Enterprise programme in Singapore, launched in 2006; the International Centres of Excellence programme in Chile (2009); and the International Partnership Programme in Portugal (2006). The expectation is that attracting "world-class" universities or PRIs will enhance the country's science base and improve science-industry links (Klerkx and Guimón, 2017; Youtie et al., 2017).

4.6. Open questions

A number of open questions remain regarding the policy mix for knowledge transfer. First, while existing studies have repeatedly emphasised that a "one size fits all" approach should be avoided, it is important to clarify what country specificities require which differentiated policy approaches. Thus, further research and policy analyses would be necessary to dig further into the relationship between national contexts and policy mixes to support knowledge transfer. What kind of methods and data sources can be used for a more systematic analysis of countries' policy mixes? What are the main country-specific variables that explain differences across countries and how can they be measured? Indicators on governance of public research across the OECD – work developed for this TIP project – can provide important inputs for analysis (Borowiecki and Paunov, 2018).

Second, this chapter has not clarified how to assess the actual impact of the policy mix on knowledge transfer. How can the impact of policies best be measured, taking into consideration the interactions among policy instruments and the different channels of knowledge transfer? To what extent are existing impact evaluation systems flawed, and how could they be improved? For a more detailed discussion of challenges to impact analysis of single instruments, see Chapter 1.

Third, more evidence and cross-country comparative analysis are necessary to clarify the implications of recent policy trends and to identify good practices. For instance, what type of co-creation schemes work better, and under which conditions? How can we determine which type of intermediary organisations are more appropriate considering a country's structural and institutional characteristics? Should intermediary organisations have a regional focus and be specialised in specific technological niches, or build new collaborations across disciplinary and geographical boundaries? Are new organisational structures needed to foster co-creation? How should the policy mix to support knowledge transfer best respond to the digital transformation and to the spread of global innovation networks?

Fourth, digital platforms to connect science with industry are proliferating and evolving rapidly. To what extent and under which conditions do they create new and improved opportunities for science to support innovation? How should technology transfer offices of public research organisations and researchers themselves interact with these digital platforms? Is there a need for public policy support of such platforms?

Finally, new diagnosis toolkits would need to be developed in order to better evaluate the quality and coherence of a country's policy mix to support knowledge transfer. What makes a good policy mix? What are the key criteria to take into consideration? How can the conceptual framework developed in this chapter be translated into more operational tools to guide policy decision making? While this chapter has provided some insights, further efforts are necessary to advance in these directions.

4.7. Conclusions

Gaining a better understanding of the policy mix is important since new policy initiatives might fail, not because of their intrinsic weaknesses but because they were not embedded in a policy mix that set the right conditions for success, including complementary policies to facilitate implementation and create synergies rather than contradictions.

Mapping policy instruments and classifying policies across different dimensions is useful for understanding the composition of the policy mix and to judge whether it is coherent. For example, the policy mix should comprise various policy instruments targeting alternative channels, rather than focusing solely on traditional, more measurable channels such as patent licensing or spin-off creation. There should be a good balance of policies addressing the barriers faced by the different target groups involved, including firms, universities/PRIs and individual researchers.

Beyond considering the composition of the policy mix, it is also critical to assess the interactions (both positive and negative) among its elements. Greater efforts are necessary to move towards evaluation methods that consider the combined effects of policy instruments, as well as potential redundancies, contradictions and remaining problems that could be addressed with new instruments. This is possible through more systematic evaluations of entire policy mixes and through introducing, within the templates used to evaluate individual policy instruments, a specific section that focuses on their interaction with the broader policy mix.

Countries' policy mixes should be regularly revised to respond to changes in the national environment, in policy learning, and in broader global trends.

References

Borowiecki, M. and C. Paunov (2018), "How is research policy across the OECD organised? Insights from a new policy database", *OECD Science, Technology and Industry Policy Papers*, No. 55, OECD Publishing, Paris, https://doi.org/10.1787/235c9806-en.

Botero Ospina, M., A.E. Sánchez Salazar and J. Pontón Silva (2019), "Technology transfer in Colombia", Case study produced for the OECD TIP Knowledge Transfer project.

Data61 (2018), *About D61 + Expert Connect*, https://expertconnect.global/about (accessed on 29 May 2018).

Ecker, B., C. Reiner and G. Gogola (2019), "Policy mix for science-industry knowledge transfer in Austria", Case study produced for the OECD TIP Knowledge Transfer project.

Encarnação, J.L. (2017), "Collaborative Laboratories – for the stimulation and reinforcement of the innovation and technology transfer in Portugal", Presentation at the workshop, Stimulating Knowledge Transfer: Challenges and Policy Responses, 8 November 2017, available at www.innovationpolicyplatform.org/system/files/Panel%201.2_Encarnacao_CoLABS.pdf.

European Commission (2019) "Joint Programming", Coordination of Research Programmes, European Research Area, available at http://ec.europa.eu/research/era/joint-programming_en.html (accessed on 25 January 2019).

Frølund, L., F. Murray and M. Riedel (2018), "Developing successful strategic partnerships with universities", *MIT Sloan Management Review*, Winter Issue, pp. 71-79.

Guerzoni, M. and E. Raiteri (2015), "Demand-side vs. supply-side technology policies: Hidden treatment and new empirical evidence on the policy mix", *Research Policy*, 44, pp. 726-747, https://doi.org/10.1016/j.respol.2014.10.009.

Halme, K. et al. (2019), "Overview of the policy mix for science-industry knowledge transfer in Finland", Case study produced for the OECD TIP Knowledge Transfer project.

Harms, H. (2018), "The funding model of the Christian Doppler Research Association", presentation at the OECD-TIP workshop, Boosting Knowledge Transfer between Science and Industry, Paris, 14 March 2018, www.innovationpolicyplatform.org/system/files/Panel%201.2_Harms.pdf (accessed on 15 February 2019).

Herstad, S.J. et al. (2010), "National innovation policy and global open innovation: Exploring balances, tradeoffs and complementarities", *Science and Public Policy*, Vol. 37, pp. 113-124.

Howlett, M. (2004), "Beyond good and evil in policy implementation: Instrument mixes, implementation styles, and second generation theories of policy instrument choice", *Policy and Society*, Vol. 23, Issue 2, pp. 1-17, https://doi.org/10.1016/S1449-4035(04)70030-2.

Hungarian National Research, Development and Innovation Office (2019), "Science-industry knowledge transfer in Hungary – Case study about the Centres for Higher Education and Industrial Cooperation", Case study produced for the OECD TIP Knowledge Transfer project.

Innovation, Science and Economic Development Canada (2019), "The Technology Access Centres (TAC) programme in Canada", Case study produced for the OECD TIP Knowledge Transfer project.

Klerkx, L. and J. Guimón (2017), "Attracting foreign R&D through international centres of excellence: Early experiences from Chile", *Science and Public Policy*, Vol. 44, Issue 6, https://doi.org/10.1093/scipol/scx011.

Knill, C. (2005), "Cross-national policy convergence: Concepts, approaches and explanatory factors", *Journal of European Public Policy*, Vol. 12, Issue 5, pp. 764-774.

Lanahan, L. and M.P. Feldman (2015), "Multilevel innovation policy mix: A closer look at state policies that augment the federal SBIR program", *Research Policy*, Vol. 44, Issue 7, pp. 1387-1402.

MacAulay, B. (2017), "Intermediation in support of effective knowledge transfer – The role of Catapults", Presentation at the workshop, Stimulating Knowledge Transfer: Challenges and Policy Responses, 8 November 2017, available at www.innovationpolicyplatform.org/system/files/Panel%205.2_MacAulay_Panel_DigitalCatapult.pdf.

Ministry of Economy, Development and Tourism of Chile (2019), “Public policy to promote technology transfer in Chile: Licensing and technology transfer offices and technology transfer hubs”, case study produced for the OECD TIP Knowledge Transfer project.

OECD (2013), *Commercialising Public Research: New Trends and Strategies*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264193321-en.

OECD (2019), *Digital Innovation: Seizing Policy Opportunities*, OECD Publishing, Paris, https://doi.org/10.1787/a298dc87-en.

Sanz, L. and L. Cruz-Castro (forthcoming), “Instruments and instrument mixes for knowledge transfer and science industry relations: A pilot analysis using STIP Compass database in selected countries”, Paper prepared for the European Commission.

Spilioti, A., V. Gongolidis and A. Gypakis (2019), “Supporting the establishment and development of spin-offs in Greece”, Case study produced for the OECD TIP Knowledge Transfer project.

Youtie, J. et al. (2017), “Institutionalization of international university research ventures”, *Research Policy*, Vol. 46, Issue 9, pp. 1692-1705, https://doi.org/10.1016/j.respol.2017.08.006.

Chapter 5. New policy practice to support spin-offs

This chapter presents an overview of different types of policy instruments that can be implemented to support the creation of spin-offs, and reflects on their possible interactions. It then discusses how country conditions influence the policy mix for spin-off support. New policy approaches are explored, including placing greater emphasis on the quality rather than the quantity of spin-offs supported, as well as on spin-offs initiated by students and early career researchers. Dimensions that are critical for the success of such approaches and the role of research and technology organisations (RTOs) are also analysed. The evidence presented in this chapter is largely based on country policy case studies.

Introduction

One important channel for knowledge transfer is the creation of spin-off companies born of technology developed at universities or public research institutions (PRIs). Spin-off dynamics are seen as critical drivers of national competitiveness in the knowledge-based economy. Support to spin-offs can also help create jobs for highly skilled personnel and offer career opportunities to students and young researchers where the economy generates few such opportunities.

Consequently, the promotion of academic spin-offs has attracted attention across OECD countries as a means for rapidly transferring new scientific knowledge into commercial use (OECD, 2013). Specific funding schemes have been introduced, incubators and science parks created, and incentive schemes put in place for scientists to create and work in spin-offs. Universities and PRIs have also invested in promoting spin-offs as both a source of income for them and an opportunity for more returns.

This chapter provides an overview of the policy options to support spin-offs and explores recent trends, including the greater attention paid to promoting the quality and not just the quantity of spin-offs, and the increased focus on student entrepreneurship.

The analysis builds upon a set of case studies developed in the course of the TIP project on knowledge transfer (2017-18). These include eight case studies on recent policy programmes to support spin-offs developed by different OECD countries, and six case studies focusing on how research and technology organisations (RTOs) contribute to spin-off development. These case studies are listed and summarised in Annex 5.A1, while the full drafts are available at the project's website.

The chapter is structured as follows. Section 5.1 describes the instruments that can go into the policy mix for spin-off support and their possible interaction, while Section 5.2 identifies recent policy trends that have shaped spin-off support. Section 5.3 discusses how country conditions influence the choice of policy mix. Section 5.4 identifies different operational dimensions of national spin-off support policies. Section 5.5 looks into RTO's schemes in support of spin-off success. Section 5.6 concludes.

5.1. The policy mix to support spin-offs: Types of policy instruments and interactions

The policy mix to promote academic spin-offs is a subset of the overall policy mix for knowledge transfer (see Chapter 4). A variety of financial, regulatory, and "soft" policy instruments are often implemented to support academic spin-offs:

- Financial instruments include direct financial support for spin-offs and funding support for infrastructures and intermediary organisations such as technology transfer offices (TTOs), incubators and science parks.
- Regulations aim at ensuring that public universities and research institutes, as well as individual researchers, are allowed to and have incentives to create and work in spin-offs.
- Soft instruments include awareness raising, networking services, mentoring, and specialised training for researchers and PhD students, with a focus on entrepreneurship.

There are also important interactions among different policy instruments to support spin-offs. As discussed in Chapter 4, positive interactions may occur in the form of precondition, facilitation or synergy effects:

- A policy instrument that is a precondition for the success of spin-off support policies is, for example, the regulatory regime in place to allow researchers to engage in spin-offs. The case study developed by Colombia for this project (Botero Ospina, Sánchez Salazar and Pontón Silva, 2019) shows how, following the introduction of new grants to support spin-offs, it was necessary to remove regulatory barriers that prevented employees of public universities and research institutes from creating a new company; this led to the enactment of a new law. Greece also introduced regulatory changes in 2014 to enable the launch of financial instruments needed to support spin-off companies (Spilioti, Gongolidis and Gypakis, 2019).
- Policy instruments that facilitate spin-offs include soft policies[1] such as support programmes that help with marketing and matchmaking services that enhance the effectiveness of financial instruments. Entrepreneurial support networks are another instrument, and one that often makes a critical difference. However, the benefits of these programmes need to be weighed against the additional costs involved in providing such support, especially if it is personalised.
- Synergies arise where financial support to spin-offs is combined with support for intermediary organisations such as incubators, TTOs, entrepreneurship centres and science parks (OECD, 2013). The benefits from such synergies include easier access to investors, human capital and training support.

Negative interactions among policy instruments may occur if they contradict each other or result in excessive complexity. This implies that the coexistence of many different instruments offered by different levels of government (local, regional, national, supranational) and implemented by various intermediary organisations (including PRIs, innovation agencies, science parks, TTOs and incubators) needs to be well co-ordinated to avoid unnecessary duplication and confusion, and to build synergies among programmes. Where multiple sources of financial support to spin-offs coexist (from different ministries, government agencies and local governments), the efficiency of the policy mix may suffer.

Moreover, interactions with the broader policy mix for knowledge transfer need to be taken into consideration. Different channels for knowledge transfer can complement each other: for example, spin-offs will be more fertile when universities already have strong links with industry in terms of research collaboration (Fischer et al., 2018). However, there might also be negative interactions among different channels: for example, excessive emphasis given to technology commercialisation through spin-offs can work to the detriment of other modes of knowledge transfer, such as R&D collaboration. In addition, the impact of spin-off activity on the other roles of universities, notably in providing high-quality research and education, needs to be considered.

Interactions with other policy domains should also be considered when assessing the policy mix to promote spin-offs. In particular, the conditions for entrepreneurship have a direct impact on the success of spin-offs and influence the propensity of academics to engage in such ventures. For example, the minimum capital requirement to start a business lowers entrepreneurship rates across countries, as do labour market regulations of starting a business.

5.2. How do country conditions influence the policy mix to support spin-offs?

Country conditions should be carefully considered when deciding which type of policy instruments would be more appropriate to support spin-offs or even whether supporting spin-offs is a viable policy objective in the first place. In addition to the country's level of socio-economic development, macroeconomic conditions and general business climate, some of the key factors to consider when assessing spin-off support policies are the country's industrial specialisation and the characteristics of its universities and PRIs.

The country's industrial specialisation is relevant to spin-off policies, since different industries may differ in their readiness to engage in spin-offs and different modalities for doing so. For example, as discussed in the case study developed by Finland (Järvelin and Hyvärinen, 2019), a 2017 evaluation of the TUTL programme in that country concluded that funding schemes to support spin-offs need to take into account that the development and commercialisation processes in the ICT sector are often very short and fast-paced, whereas in the pharmaceutical sector the process from product development and testing to commercialisation takes years.

Spin-off policies should support not only high-technology sectors (such as ICT, pharmaceuticals and aeronautics), but also traditional sectors (such as agriculture, tourism and textiles). Indeed, spin-off dynamics around applications of digital technologies, big data and artificial intelligence may span a variety of industrial sectors. New spin-offs based on applications of such technologies in traditional sectors can greatly contribute to the economy by developing new market niches, building new networks, and increasing the productivity of existing firms.

The strengths and entrepreneurial orientation of universities and PRIs, both across and within countries, are also important to consider (Kalar and Antoncic, 2015; Rasmussen and Borch, 2010). For example, when universities and PRIs lack the appropriate infrastructure and capabilities to promote spin-offs, policies may need to focus on creating the necessary intermediary organisations such as incubators and science parks before providing direct financial support to spin-offs. The 2017 evaluation of the TUTL programme in Finland mentioned above also suggested that policy programmes should differentiate between the more traditional universities in Finland that focus more on humanities and social sciences and so far have little experience with commercialisation, and the universities with a stronger focus on technology with more experience commercialising.

5.3. New policy approaches: focusing on quality and student entrepreneurship

Policies to support spin-offs have changed in recent years across many OECD countries. Among other changes, new policy approaches have emerged along the following two dimensions.

First, policy support is paying increasing attention to more advanced stages of the spin-off life cycle. This shift reflects a growing concern over sustainability and growth, since only a very small proportion of spin-offs actually become high-growth firms that contribute to economic growth and employment creation (Shane, 2009). Rather than increasing the quantity of spin-offs, recent policy approaches emphasise *quality* by providing stronger support to those spin-offs that demonstrate strong potential (Fischer et al., 2018). As part of this trend, direct grants and early stage funding are increasingly complemented with equity finance through public venture capital (Menon, 2018). The case studies developed by Greece and Norway for this OECD project describe how national governments have created new public venture capital funds to support spin-offs, given the insufficient activity of private venture capital funds.

Second, greater attention is also placed on promoting spin-offs initiated by students and early career researchers (e.g. post-docs), and not only on those initiated by well-established professors and scientists (Bischoff, Volkmann and Audretsch, 2018; Jansen et al., 2015). If student entrepreneurship works properly, new employment opportunities for the young people are created and better connections between scientific knowledge and industry can be established. Student entrepreneurship can be promoted by i) integrating entrepreneurship training in educational programmes more explicitly and ii) providing direct support to student-led technology-based spin-offs. On the one hand, measures to promote student entrepreneurship through education may include the introduction of new courses on entrepreneurship across all disciplines, internship programmes and industrial PhD programmes, among others. On the other hand, policies to support student-led spin-offs can include mentoring, networking services, business plan competitions, office space in incubators or science parks, accelerator programmes, and dedicated funding schemes.

An example of the latter trend is the French national initiative PÉPITE, which has established 29 centres throughout the country that have provided support to around 8 000 students since 2014, including: i) access to FabLabs, connector places, digital tools and resources, dedicated co-working areas, mentoring and training; ii) an annual prize to student entrepreneurs that awards between EUR 5 000 and EUR 20 000 to over 50 projects; and iii) specific status ensuring continuity of student social security while developing a start-up. In addition, tax breaks and social security exemptions are provided to firms that recruit recent master's/PhD graduates, as managers or shareholders of innovative or university-based companies.

5.4. The operational dimensions of spin-off policies that were critical to their success

Recent international experiences, as illustrated by the case studies developed for this project (see Annex 5.A1), provide insights into successful operational approaches in the implementation of spin-off support policies.

First, adopting a regional approach facilitates implementation and allows focusing on the specific priorities of each region. Some relevant examples include the following cases:

- In the Netherlands, the Valorization Programme, introduced in 2010, offered financial support to 12 consortia of regional actors in order to support the professionalisation of entrepreneurship education and valorisation structures across the country's regions.
- Programmes can also be implemented throughout a country's regions in a sequential manner. This was the case with the ICURe programme in the United Kingdom, initially launched in 2014 as a pilot in the South of England through a partnership involving the TTOs of five universities in the region. Based on the pilot's positive results, the programme was expanded to other regions.
- In Austria, the AplusB Programme has supported academic spin-offs since 2001 through seven centres that provide incubation services, including training and coaching. Recent evaluations raised the need for better national-regional co-ordination and definition of interfaces with private incubators, to avoid duplications and gain efficiency. This led to a reform of the programme in 2017.

Beyond national-regional co-ordination, several case studies emphasise the need for efficient horizontal co-ordination of the different policy programmes run by different ministries or agencies. With regard to the interactions among various policy instruments, the case study of Greece illustrates how, at the time of introducing new public funding schemes to support spin-offs, it is important to avoid contradictions and duplications with other pre-existing financial instruments. Interactions between financial and other regulatory and soft instruments are also critical, as discussed in the case study from Colombia. After introducing financial grants to support spin-offs in 2010, the Colombian government later found it necessary to complement the measure: it introduced guidelines providing practical tools to support universities in 2015, and a new law empowering researchers to create spin-offs that was enacted in 2017. These kinds of interactions between policy programmes and agencies highlight the importance of considering the mix of instruments in policy design and evaluation.

Another lesson from recent policy experiences relates to the advantages of adopting flexible and bottom-up forms of policy intervention that allow for experimentation. The case study from Costa Rica illustrates how a process of "open policy experimentation", including seven interactive workshops with over 140 key stakeholders, was useful in ensuring a bottom-up development of policy measures to support spin-offs across different institutions that responded to stakeholders' needs.

5.5. How are RTOs contributing to the success of spin-offs?

Academic spin-offs are also supported by the specific regulations and support schemes offered by their institutions of origin. This section will focus in particular on how research and technology organisations (RTOs) lend their support to spin-offs. RTOs are applied research organisations focusing on the development and transfer of science and technology to industry and society at large. Most countries have developed such types of intermediary organisation over the years; these may be publicly or privately owned, but are normally strongly supported by public funding and operate on a non-for-profit basis.

During the past decade, RTOs have developed new programmes to promote spin-offs on the basis of their research. They have also substantially increased their investments in such ventures. The following sequential lines of support are usually offered by these institutions in their efforts to stimulate the creation of successful spin-offs:

- Awareness building and specialised training in entrepreneurship provided to RTOs' employees.
- Regular rounds of presentations by research teams to identify relevant technological development and select the most promising projects.
- In-house business incubation programmes for selected projects, including specialised training, coaching and mentoring; networking with external agents (e.g. venture capital funds, business angels, potential customers or partners, etc.); and dedicated grants (e.g. for patenting, proof-of-concept or/and prototype development).
- The possibility for spin-offs to benefit from office space within the institution after the company is created, during a certain period and under varying economic conditions depending on the institution.
- In some cases, RTOs participate with equity funding in the spin-off, by making a monetary or in-kind contribution.

In recent years, three key trends have emerged with the operational approaches and governance mechanisms to support spin-offs in the sample of six RTOs that contributed case studies to this project (see Annex 5.A1, Table 5.A1.).

First, RTOs have all created within their premises dedicated units or departments charged with promoting spin-offs. These include the Start-Up Unit of the CEA (France), Eurecat's Valorisation Area, Fraunhofer Venture (Germany), Tecnalia Ventures (Spain), the Technology Transfer team at the TNO (Netherlands), and VVT Ventures (Finland). These newly created structures provide specialised support services and different kinds of funding schemes, increasingly including dedicated venture capital funds.

Secondly, these RTOs are also building more intense connections with other actors in their ecosystem to achieve their goals. For example, Fraunhofer has partnered with UnternehmerTUM, the innovation centre of the Technical University of Munich, to provide support to spin-offs within the context of their FDays acceleration programme. Likewise, TNO collaborates with Yes!Delft, a Dutch incubation association. Moreover, all RTOs collaborate with other incubators, venture capital funds, consultants, and firms that may be interested in their technologies.

A third common trend is the establishment of clear guidelines regarding the level of involvement of their employees in newly created spin-off companies. For example, at TNO, a "hybrid employees" model has been developed whereby TNO employees working on a spin-off sometimes can retain their job at TNO on a full-time or part-time basis. Likewise, the internal policy of VTT allows its researchers to take a one-year leave of absence so that as a back-up plan they can return to VTT from the spin-off within that 12-month period. At Eurecat, employees can request authorisation to participate in the equity of, collaborate with, and/or work temporarily for a spin-off.

5.6. Conclusions

This chapter has provided an overview of policy instruments used by OECD countries to support academic spin-offs. National policies include a variety of financial, regulatory and soft policy instruments. These should be integrated within a coherent policy mix adapted to each country's specific institutional and structural characteristics. Besides the composition of the policy mix, it is also necessary to assess the interactions among the different policy instruments.

Case studies illustrate recent policy programmes implemented in a variety of OECD countries. Recent trends in the policy mix to support spin-offs include greater attention paid to promoting the quality and not just the quantity of spin-offs, and an increased focus on student entrepreneurship.

In addition to national policies, at the institutional level universities and PRIs are increasing their efforts to support the creation and success of spin-offs. That institutional level of governance is becoming increasingly important as universities and PRIs attain greater levels of autonomy (Chapter 6).

References

Bischoff, K., C.K. Volkmann and D.B. Audretsch (2018), "Stakeholder collaboration in entrepreneurship education: An analysis of the entrepreneurial ecosystems of European higher educational institutions", *The Journal of Technology Transfer*, Vol. 43, pp. 20-46.

Botero Ospina, M., A.E. Sánchez Salazar and J. Pontón Silva (2019), "Technology transfer in Colombia", Case study produced for the OECD TIP Knowledge Transfer project.

Fischer, B.B. et al. (2018), "Quality comes first: University-industry collaboration as a source of academic entrepreneurship in a developing country", *The Journal of Technology Transfer*, Vol. 43, pp. 263-284.

Jansen, S. et al. (2015), "How education, stimulation, and incubation encourage student entrepreneurship: Observations from MIT, IIIT, and Utrecht University", *The International Journal of Management Education*, Vol. 13, pp. 170-181.

Järvelin, A.M. and J. Hyvärinen (2019), "TUTL - New Knowledge and Business from Research Ideas", Case study produced for the OECD TIP Knowledge Transfer project.

Kalar, B. and B. Antoncic (2015), "The entrepreneurial university, academic activities and technology and knowledge transfer in four European countries", *Technovation,* Vol. 36, pp. 1-11.

Menon, C. (2018), "Mixing experimentation and targeting: Innovative entrepreneurship policy in a digitised world", *OECD Science, Technology and Innovation Outlook 2018: Adapting to Technological and Societal Disruption*, OECD Publishing, Paris, https://doi.org/10.1787/sti_in_outlook-2018-en.

Motohashi, K. (2018), "University based innovation in Japan", presentation at the OECD-MIT Workshop Towards Effective Science-Industry Co-creation, OECD, Paris, 5 December 2018, www.innovationpolicyplatform.org/workshop-towards-effective-science-industry-co-creation/presentations-oecd-mit-workshop-december-2.

OECD (2013), *Commercialising Public Research: New Trends and Strategies*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264193321-en.

Rasmussen, E. and O.J. Borch (2010), "University capabilities in facilitating entrepreneurship: A longitudinal study of spin-off ventures at mid-range universities", *Research Policy*, Vol. 39, pp. 602-612.

Shane, S. (2009), "Why encouraging more people to become entrepreneurs is bad public policy", *Small Business Economics*, Vol. 33, pp. 141-149.

Spilioti, A., V. Gongolidis and A. Gypakis (2019), "Supporting the establishment and development of spin-offs in Greece", Case study produced for the OECD TIP Knowledge Transfer project.

Annex 5.A1

Summary of the case studies

Table 5.A1.1. **Case studies on national programmes to support spin-offs**

Country	Brief description
Austria	The AplusB Programme has supported academic spin-offs since 2001 through seven centres that provide incubation services, including training and coaching. Recent evaluations raised the need for better national-regional co-ordination and definition of interfaces with private incubators, to avoid duplications and gain efficiency. This led to a reform of the programme in 2017. In addition, a new programme called Spin-off Fellowships was launched in 2017 with a focus on supporting spin-offs from young scientists and students. The Austrian Startup Monitor initiative, launched in 2018, monitors the evolution of start-ups in Austria.
Colombia	Financial grants to support spin-offs were introduced in 2010. In 2015, a guide for the creation of spin-offs was developed as a practical tool for universities to support spin-offs. In 2017 a new law was enacted empowering universities to create spin-offs with the active participation of researchers.
Costa Rica	Recent policy programmes have been introduced to support spin-offs, including financial instruments (grant schemes) and “soft” instruments (workshops, networking events, etc.). In order to develop a locally appropriate approach to support spin-offs, a process of “open policy experimentation” was very useful, including seven interactive workshops with over 140 key stakeholders.
Finland	The TUTL programme, launched in 2011, provides grants for research groups and researchers who want to build a new business based on their research. TUTL was introduced to focus on the early stage of the spin-off process, complementing pre-existing programmes for more advanced stages. An evaluation conducted in 2017 concluded that it has successfully met a gap in the national innovation system.
Greece	A grant programme to support spin-offs has been available since 2001. In 2018 it was decided to complement it with a public venture capital fund to provide equity finance. At the time of introducing the venture capital fund, it was necessary to make some adjustments to avoid negative interactions with the pre-existing grant scheme.
Netherlands	The “Valorization” programme was introduced in 2010 to support the professionalisation of entrepreneurship education and valorisation structures. The programme offered financial support to 12 consortia of regional actors. The region-specific approach facilitated implementation and permitted a focus on the specific priorities of each region.
Norway	Several policy programmes run by different agencies provide support to spin-offs. They involve different support services, financial grants and incubation facilities. Support to spin-offs has expanded substantially in recent years with increased funding. In view of the financial difficulties faced by already established spin-offs in their early years of operation, new public venture capital funds (Argentum and Investinor) have been created, and public seed capital funding schemes have been expanded.
United Kingdom	The ICURe pilot programme was launched in 2014 to support teams of academic researchers wishing to explore the commercial potential of research originating in universities. The programme was first implemented through a partnership involving the TTOs of five universities in one region, and then expanded to other regions.

Table 5.A1.2. **Case studies on spin-off support schemes provided by European RTOs**

RTO (Country)	Approach to support spin-offs	Results
CEA (France)	• Ongoing entrepreneurship training to employees. • Regular presentations and selection of promising projects. • Business incubation programme for selected projects (incubation periods are set for a period of 6 months, renewable a maximum of 2 times). • Dedicated financial vehicles to provide seed funding to more advanced projects (since 2017).	9 new spin-offs created in 2017 and 103 during 2008-17. Of these, 15 currently have more than 20 employees and 16 had sales of more than EUR 1 million.
Eurecat (Spain)	• Services to different stages of spin-offs, from awareness building to road-to-market. • Spin-offs can request office space in the premises of Eurecat and benefit from support services. • Eurecat does not normally provide direct funding to spin-offs but participates in the search for public or private financing.	Currently participates in 8 spin-offs. Performs analysis of viability of around 2 new business initiatives per year.
Fraunhofer (Germany)	Offers 4 sequential lines of support to spin-offs: • Business Ideation: pre-qualification programme, including workshops where employees develop business ideas and test their market potential. • Fraunhofer Days (FDays): 12-week acceleration programme that acts as a stress test for market, team, and technology. • Fraunhofer Fosters Entrepreneurs: business plan development and specific support in the preparations for founding the spin-off, sometimes with equity investment by Fraunhofer. • Fraunhofer Fosters Management: financial support for completing management competencies, including coaching to existing team of founders and sometimes also financial support to hire an experienced manager.	25 new spin-offs created in 2017 and around 26 in 2018. This represents a ratio of 1.4 spin-offs per 1,000 researchers per year, which is high by international standards for comparable RTOs.
Tecnalia (Spain)	• Provides acceleration, incubation and venture building services to the most promising technology research groups. • A focus on "market pull" technology development brings the view of "what investors want" into the process early, articulated around an innovative accelerator incubator programme called Omega. • An Inspiring Business Forum (IBF) was created, comprising around 25 leading companies in the region potentially seeking technology-based opportunities offered by TECNALIA.	1 new spin-off created in 2017 and 2 in 2018. Current portfolio of 14 spin-off companies, with overall annual turnover of EUR 33.5 million and 267 employees. On average at any time circa 40 business opportunities are in the accelerator.
TNO (Netherlands)	• Upon approval of the application of a project for admission to phase 1 of the programme, a maximum budget of EUR 30 000 is allocated for 3 months. • Those that are selected for phase 2 (Preparations for spin-off) receive up to EUR 50 000 for 6 months. • TNO may participate in a spin-off as a minority shareholder but does not make cash investments. • In some cases, spin-offs are allowed to continue making use of TNO facilities such as offices or laboratory spaces.	5 new spin-offs were launched in 2017. A total of 27 companies participated in different phases of the Technology Transfer Program in 2017.
VTT (Finland)	• Support for maturing the idea and technology together with the researchers using VTT industry networks. • Coaching the research team with the business planning, financial numbers, legal documentation (through a VTT legal advisor), investor pitch and presentation materials. • Introducing the team and opening doors for them to meet other potential investors (venture capital firms, corporates, business angels). • Scouting for additional professionals to join the project. • VTT Ventures manages a fund that invests in spin-offs.	20 companies in the portfolio at the end of 2017, which had 486 full-time employees and net sales of EUR 34 million. On average 3 new spin-offs created per year.

[1] Soft policy instruments are less interventionist modes of public policy than financial or regulatory instruments; they focus on facilitating relationships, mobilising, networking, integrating, and building trust.

Chapter 6. Governance of public research and its implications for knowledge transfer

This chapter presents new evidence on governance of public research supporting knowledge transfer, based on a new survey conducted in 2017-18 for this project across 35 OECD countries. It first provides new evidence on the level of autonomy of universities and PRIs, which impacts their capacity to make decisions regarding support programmes for knowledge transfer. It then explores the importance of performance contracts and evaluation mechanisms that incentivise knowledge transfer. It also provides insights into the participation of civil society and industry on the governing boards of universities, PRIs and research councils.

Introduction

The effectiveness of the policy mix for knowledge transfer depends on the quality of the governance of public research, i.e. the institutional arrangements that govern policy action regarding publicly funded research in universities and public research institutions (PRIs). Instruments will operate differently depending on how universities and PRIs are empowered (or not) in shaping their own ways of reaching set targets. Interaction among different levels of governance (e.g. national with regional) may create synergies but may also lead to duplications and unnecessary complexity in the absence of efficient co-ordination mechanisms. Therefore, when assessing a country's policy mix for knowledge transfer it is important to analyse the institutions and governance systems that determine how policy instruments are designed and implemented.

The focus in this chapter is on recent trends in the governance of public research in relation to science-industry knowledge transfer, based on a new survey conducted in 2017-18 across 35 OECD countries for this project (Borowiecki and Paunov, 2018).[1]

The chapter notes the following important characteristics of the governance of public research across the OECD area that shape knowledge transfer.

- With regard to policy implementation, universities and PRIs have achieved autonomy across many member countries, allowing them to deploy their own support programmes for knowledge transfer. Autonomy with regard to managing industry relations in particular is widespread.
- As to contributions to knowledge transfer, an increasing number of OECD countries have established performance contracts between national ministries/agencies and universities/PRIs. Such contracts can stimulate knowledge transfer by including not only traditional targets related to teaching and research, but also other targets associated with their engagement with firms and the commercialisation of their research results.
- Regarding engagement with private firms, these are increasingly participating in the governing boards of universities, PRIs and research councils to offer their perspectives. This may lead to a greater orientation of such institutions towards innovation and knowledge transfer.

The chapter is structured as follows. Section 6.1 provides new evidence on the level of autonomy of universities and PRIs in the OECD area. Section 6.2 focuses on performance contracts and other evaluation mechanisms that incentivise knowledge transfer. Section 6.3 analyses the participation of industry on the governing boards of universities, PRIs and research councils. Section 6.4 concludes.

6.1. The autonomy of universities and PRIs

Over the past decades, universities and PRIs have achieved greater autonomy across the OECD area, allowing them to deploy their own support programmes for knowledge transfer on top of those offered across the board by the national and regional governments. In France for example, universities have been free to establish their own for-profit entities and joint R&D with industry since 2011 (Freedom and Responsibilities for Universities Act 2011). In Portugal, universities were granted more autonomy by Law 62/2007 of 10 September 2007 on Higher Education Institutes (RJIES). In Austria, they gained full autonomy over financial and organisational affairs in 2002 (University Act).

The trend towards greater autonomy allows for a wider variety of approaches to promote knowledge transfer across different universities and PRIs even within a single country, making it more challenging to characterise a country's policy mix based on simple taxonomies.

The autonomy of universities also influences the share of IP revenues that researchers may receive, which as mentioned in Chapter 4 (Table 4.1) is a relevant type of regulation influencing knowledge transfer. In 16 of 33 countries for which information is available, universities themselves set those revenue-sharing schemes, while in 17 countries national guidelines set the share that researchers receive (Borowiecki and Paunov, 2018). Where national guidelines exist, the share for researchers is often set between 33% and 50%. Sweden is a notable exception and grants 100%, a practice referred to as professor's privilege. In contrast, 100% of revenue accrues to universities in Latvia.

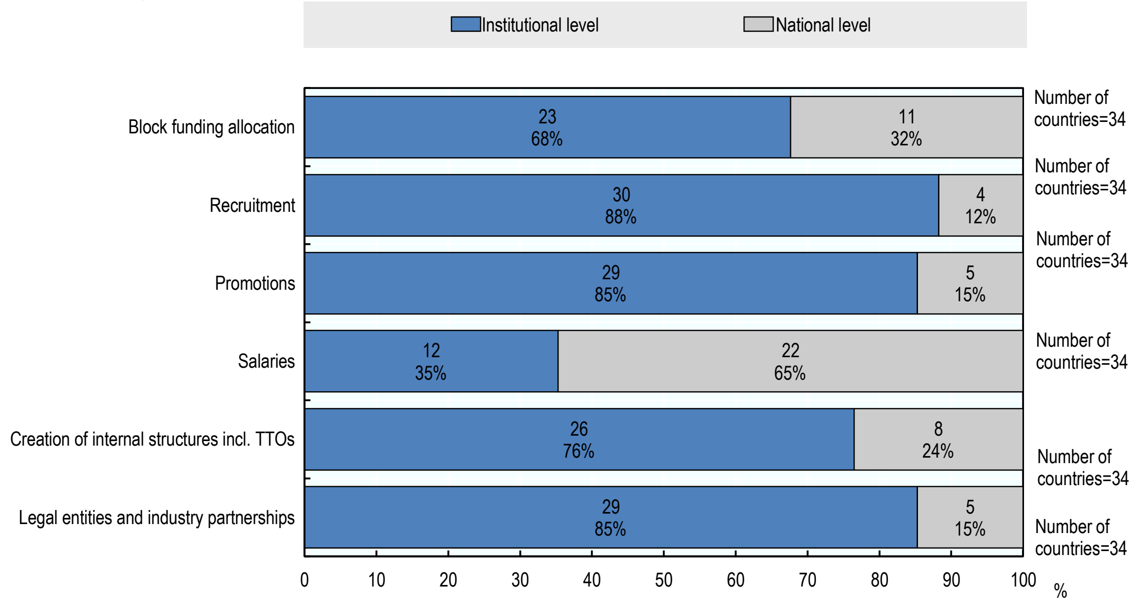
Figure 6.1 shows the extent to which universities (Panel A) and PRIs (Panel B) are autonomous across the OECD area, with PRIs having autonomy in more countries across all dimensions. Regarding industry relations, Panel A shows that 26 of 34 countries (or 76%) report that universities can decide on the creation of academic departments (e.g. research centres in specific fields) and functional units (e.g. TTOs), and in 29 of 34 countries (85%) they can create legal entities (e.g. for-profit spin-offs) and industry partnerships (e.g. joint R&D units). A similar picture emerges for PRIs (Panel B): 24 of 27 countries (or 89%) report PRIs can decide on the creation of academic departments and functional units such as TTOs, and in 25 of 27 countries (93%) PRIs can create legal entities and industry partnerships.

In terms of budget decisions, Panel A shows that in 23 of 34 (68%) OECD countries, public universities themselves decide about allocations of institutional block funding to teaching, research, and innovation activities. In the other 11 countries (32%), national laws or guidelines restrict the internal allocation of funds across budget items, such as personnel costs and capital expenditures. Regarding PRIs, in 23 of 29 (79%) countries PRIs can allocate their budget allocations freely while 6 countries (21%) report nationally binding laws or guidelines (Panel B).

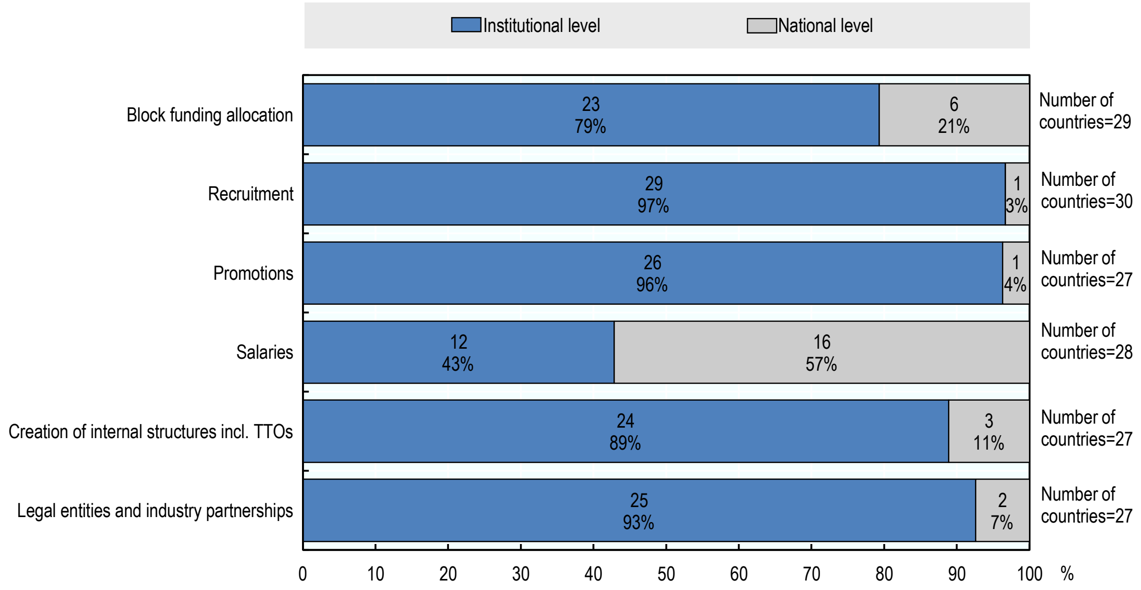
As to hiring and promoting staff, public universities are free to decide on the recruitment of academic staff in 30 of 34 (88%) OECD countries, and in 29 of 34 countries (or 85%) they are free to decide on promotions (Panel A). PRIs are free to decide about recruitment in 29 of 30 countries (97%), and about promotions in 26 of 27 countries (96%) (Panel B). Universities and PRIs enjoy less autonomy with regard to salaries: Panel A shows that only in 12 of 35 countries (or 35%) universities can freely set the salaries of academic staff, while Panel B shows that PRIs are free to decide about the level of salaries in 12 of 28 countries (43%).

Figure 6.1. **Autonomy of universities and PRIs across the OECD area**

Panel A: Autonomy of universities



Panel B: Autonomy of PRIs

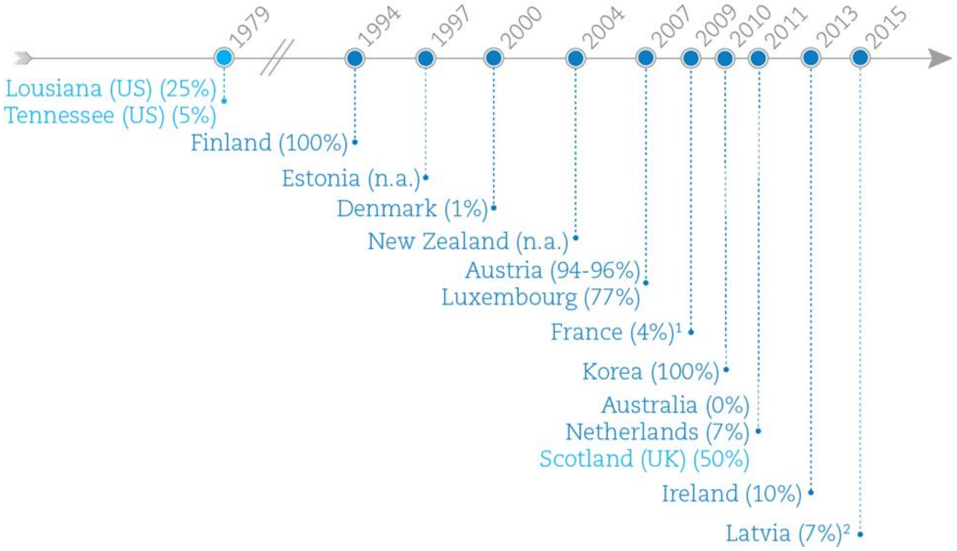


Source: Borowiecki and Paunov, 2018

6.2. Performance contracts and other evaluation mechanisms

Along with the greater autonomy accorded universities and PRIs, many OECD countries have established performance contracts between national ministries/agencies and universities/PRIs. Such contracts set performance targets and in most cases bind a share of their block funding allocation to reaching those targets. The targets aim to promote knowledge transfer by providing incentives for universities and PRIs that engage with industry and commercialise the results of their research.

Figure 6.2. **Year of introduction of performance contracts and shares of universities' institutional block funding involved**



Note: [1] In France, the share involves 4% of operating costs of French HEIs (excluding payroll). France introduced contracts between the State and higher education institutions already in 1989. In 2007, the Law on the Freedoms and Responsibilities of Universities established compulsory multi-year performance contracts with the objective to foster a strategic dialogue between the State and HEIS, taking into account their newly gained autonomy. In 2009, the first multi-year performance contracts were concluded between the French government and HEIs.

[2] In Latvia, performance-based funding was introduced in 2015 (so-called 2nd pillar funding for HEIs). It is a separate envelope of the state budget for which HEIs compete. The allocation of this funding depends on their annual performance compared to that of other HEIs.

Source: Borowiecki and Paunov, 2018, with updated information for France and Latvia as of February 2019.

In addition to traditional targets related to education and research (such as number of PhD graduates or number of scientific publications), performance contracts often include target indicators aimed at stimulating knowledge transfer. Such indicators include the number of patents filed (e.g. Australia, Korea and Luxembourg); revenue from licensing IP and contract research (Australia, Korea, Luxembourg and Scotland in the United Kingdom); industry-funded R&D (Estonia, Finland and North Rhine-Westphalia in Germany); the number of spin-offs of students and researchers (Australia, Denmark, Ireland, Korea, Luxembourg and New Zealand); the number of collaborations with industry (Australia, Denmark and Ireland); and the number of innovation vouchers for particular science-business collaborations (Scotland in the United Kingdom).

Performance contracts are in place in 13 countries (of 35 OECD countries, 37%) and in a number of regions/federal states (Scotland in the United Kingdom; Louisiana and Tennessee in the United States; Baden Wurttemberg, Brandenburg, and North-Rhine Westphalia among other federal states in Germany). Eight of the 13 OECD countries with performance contracts in place and Scotland in the United Kingdom introduced these in the past decade (Figure 6.2). Australia (2011) introduced performance contracts that do not bind funding of universities. Slovenia is currently in the process of introducing performance contracts. Norway is now rolling out a pilot exercise with five universities and aims to have a performance contract system in place in 2019. Finland is an early adopter country: the Ministry of Education and Culture (MEC) has had performance contracts with universities since 1994. The shares of block funding subject to performance contracts varies from 1% in Denmark, 4% in France, and 7% in Latvia and the Netherlands, to 94-96% in Austria 100% in Finland (Figure 6.2).

Two other relevant trends are the inclusion of indicators related to knowledge transfer within the evaluation criteria used in *ex ante* and *ex post* evaluations, and performance monitoring of universities and PRIs. In 23 of 34 OECD countries (68%), national or regional ministries of education, research and/or innovation set the criteria for assessing performance. Dedicated agencies are increasingly important for systematic evaluation and monitoring of performance of universities and PRIs. Nineteen of 34 countries (59%) have such dedicated agencies.

The National Agency for the Evaluation of Universities and Research Institutes (ANVUR) in Italy illustrates this trend nicely, as discussed in that country's case study produced for this project (Blasi et al., 2019). In 2010, ANVUR introduced a new method for evaluating the third mission activities of Italian universities and research institutes to the private sector and wider society, to complement its existing evaluation methods. To facilitate this evaluation ANVUR has created, in collaboration with the Italian Ministry of Education, University and Research, a dedicated template with compiling instructions and an associated database; these constitute a source of comparable and highly standardised data from all the private and public universities and research centres in Italy. Besides the technology transfer activities traditionally considered (intellectual property management, academic entrepreneurship and third party funding), other activities for evaluation have been universities' investment in incubators and science parks; cultural heritage management; public health; lifelong learning; and public engagement activities. However, ANVUR has recommended that the ministry not consider for now the third mission evaluation as part of the performance-based formula funding for universities, which allocates up to 30% of government block funding to universities and research institutes.

More broadly, the case study of Russia (Zaichenko and Meissner, 2019) illustrates how recent reforms in the governance of universities and PRIs have influenced knowledge transfer. As a result of ongoing reforms, public funding for research is now increasingly allocated on a competitive basis, taking into account performance evaluation, excellence-based promotion and contribution to national priorities. The shift towards a more competitive research funding system has raised the quality of public research and reoriented it towards the needs of industry, promoting knowledge transfer.

6.3. Industry participation in the governing boards of universities, PRIs and research councils

In most OECD countries, universities' governance structure includes a board as the main decision-making body in charge of priority setting. As shown in Figure 6.3, the private sector participates in the governing boards of universities in 25 of 34 countries (74%). Such participation enhances the propensity of institutions to co-operate with industry and support knowledge transfer. In most cases business representatives are from large firms, but some countries such as Iceland and Ireland also include representatives from small and medium-sized enterprises (SMEs). Industry representation on university boards is a recent development in some countries. In France for instance, representation of business, labour unions and local actors on the governing boards of universities and PRIs was introduced by the Law on Higher Education and Research in 2013. In Portugal, university reforms in 2007 introduced the representation of external stakeholders on the governing boards of universities.

Figure 6.3. **Who formally participates on public university boards?**

	AUS	CHE	GBR	IRL	ISR	NZL	USA		DNK	AUT	BEL-FL	CAN	ESP	FIN	ISL	NLD	NOR	PRT	SWE	POL	DEU			FRA	HUN	JPN	SVN	SVK	ITA	KOR	GRC	CHL	CZE	LUX	LVA	MEX	TUR	Share of countries with boards
							USA-MA	USA-CA													DEU-BW	DEU-NW	DEU-BB															
Private sector	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X										74% 25 of 34
Civil society	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X								68% 23 of 34
Foreign experts	X	X	X	X	X	X	X	X	X																			X			X							29% 10 of 34
No formal representation																																X	X	X	X	X	X	18% 6 of 34

Source: Borowiecki and Paunov, 2018.

The private sector is also becoming increasingly involved in the policy-making process through its participation in research and innovation councils. These councils, present in 32 of 35 (91%) OECD countries, play a key role in the development of national STI strategies. Most councils include private sector representatives (in 26 of 32, or 84%), which contributes to better aligning the policy mix for knowledge transfer towards industry needs.

6.4. Conclusions

This chapter has provided new evidence on relevant trends in the governance of public research that help promote the knowledge transfer activities of universities and PRIs.

The trend towards greater autonomy enables universities and PRIs to implement their own knowledge transfer support schemes – potentially leading to more tailored incentives, but also resulting in a wide variety of approaches even within a single country. This makes it more necessary than ever for national governments to monitor existing practices across different institutions and to facilitate the exchange of experiences and good practices.

The increasing autonomy of universities and PRIs has been accompanied in many OECD countries by the establishment of performance contracts between them and national ministries/agencies. These contracts can stimulate knowledge transfer by including not only traditional targets related to teaching and research, but also other targets associated with engagement with firms and commercialisation of research results. Performance contracts are in place in 37% of the sampled countries, but it is likely that additional OECD countries will embrace this trend in the near future. Thus, it would be interesting to support mutual learning by diffusing the experiences of pioneering countries – the success stories but also the challenges faced in the process of adopting such governance mechanisms.

Industry's increasing participation in the governing boards of universities, PRIs, and research councils also has a clear influence on knowledge transfer. However, it remains to be explored how private participation can best be organised in different contexts to ensure the efficient involvement of firms in consultative and decision-making processes.

Notes

[1] The database is publicly available on the following webpage: https://stip.oecd.org/resgov.

References

Blasi, B. et al. (2019), "A new method for evaluating universities' third mission activities in Italy", Case study produced for the OECD TIP Knowledge Transfer project.

Borowiecki, M. and C. Paunov (2018), "How is research policy across the OECD organised? Insights from a new policy database", *OECD Science, Technology and Industry Policy Papers*, No. 55, OECD Publishing, Paris, https://doi.org/10.1787/235c9806-en.

Zaichenko, S. and D. Meissner (2019), "Knowledge triangle governance in Russia's policies and universities", Case study produced for the OECD TIP Knowledge Transfer project.

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University-Industry Collaboration

NEW EVIDENCE AND POLICY OPTIONS

This report discusses challenges and opportunities in assessing the impacts of science-industry knowledge exchange on innovation. The report provides new evidence on joint industry-science patenting activity and academic start-ups, as well as on the impact of geographical proximity between research institutions and industry on local innovation. The report explores the complex set of knowledge-transfer channels, such as collaborative research, co-patenting, academic spinoffs, and their relative importance across science fields and industry sectors. It also experiments with using labour force survey data to assess the contributions of graduates in social sciences to different industries.

Different policy mixes are used in OECD countries to stimulate science-industry knowledge transfer. This report presents a taxonomy of 21 policy instruments, which include grants for collaborative university-industry research and financial support to university spin-offs, and discusses their possible positive and negative interactions. Based on a number of country case studies, the report also sheds light on new policy approaches to support spin-off creation. The report also explores recent trends on the governance of public research of high relevance to science-industry knowledge transfer using newly developed policy indicators for 35 OECD countries.

Consult this publication on line at ***https://doi.org/10.1787/e9c1e648-en***.

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