

SCIENCE-INDUSTRY KNOWLEDGE EXCHANGE

A MAPPING OF POLICY INSTRUMENTS
AND THEIR INTERACTIONS

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SCIENCE-INDUSTRY KNOWLEDGE EXCHANGE: A MAPPING OF POLICY INSTRUMENTS AND THEIR INTERACTIONS

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ABSTRACT

Countries deploy a variety of financial, regulatory and soft policy instruments to promote science-industry knowledge exchange. While these instruments are often discussed in isolation, they are implemented collectively and may reinforce and complement but also weaken or even negatively affect each other and add excessive complexity. This paper develops a conceptual framework to map policy instruments for knowledge exchange and assess the interactions between them. The framework also considers how national contexts and global trends influence the choice of policy instruments. Policy examples drawn from the EC-OECD STIP Compass database and from case studies show that there are significant differences across countries in the relative importance given to each policy instrument in terms of budget, target groups, eligibility criteria, time horizon and implementation. These differences are also a consequence of different country conditions.

Keywords: policy-mix, policy instrument, knowledge transfer, co-creation, public research, intermediary organisations, evaluation, interaction, intellectual property, collaboration, spin-offs.

JEL codes: H11, I23, I28, O38

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Executive summary

This paper develops an ontology of the policy instruments to support science-industry knowledge transfer and offers insights on the policy mix across OECD countries. Adopting a policy mix approach involves paying more attention to the interactions between policy instruments.

Mapping policy instruments

The mapping exercise identifies 21 types of policy instruments that are used to support industry-science knowledge transfer in OECD countries. These include grants for collaborative research; tax incentives for firms that purchase services from universities and public research institutes (PRI); financial support to university spin-offs; mobility schemes for researchers; open access to publicly-funded research; and networking events or joint road-mapping exercises with the actors involved in science-industry links.

Most OECD countries use similar policy instruments but in different ways in terms of budget, target groups, eligibility criteria, time horizon and implementation.

Policy instruments are classified according to several criteria, including: *i*) whether they are financial, regulatory or soft instruments; *ii*) whether they target primarily firms/industry, researchers or universities/PRI; *iii*) the type of knowledge transfer channels being addressed; and *iv*) the instruments' supply- or demand-side orientation.

New forms of policy intervention are also emerging and include adapting knowledge exchange to the digital age (e.g. by building digital platforms), emphasizing knowledge co-creation (e.g. by facilitating joint labs) and connecting to the global knowledge base (e.g. by attracting leading universities from abroad).

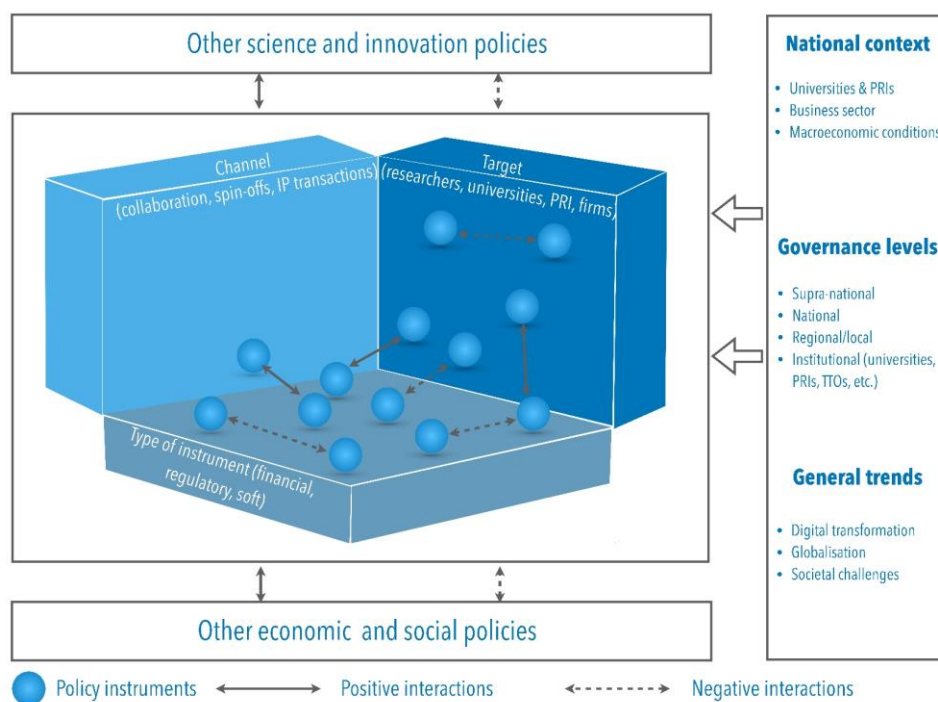
Assessing the policy mix

Assessing the policy mix for knowledge transfer requires analysing the different types of policy instruments and the interactions between them, while considering the influence of national contexts and global trends of relevance to knowledge transfer (Figure 1).

The combination of several policy instruments may create synergies but also weaken the success of individual instruments. An example is offering grants for collaborative university-industry research projects without providing support services and appropriate regulations and guidelines for IP management. In addition, the coexistence of too many different policy instruments may weaken the impact of single instruments with funding split among a large number of programmes. Co-ordination challenges may also arise when actors find themselves with diverse funding options.

Aside from the interactions between policy instruments aimed at supporting knowledge transfer, potential interactions with other science and innovation policies and with 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.

Figure 1. Conceptual framework



A cohesive policy mix requires co-ordination across multiple actors from government and from outside the government. Policies to foster knowledge transfer are also designed and implemented at the institutional level i.e. by public universities and research institutes themselves and different kinds of “intermediary organisations” to implement knowledge transfer policies, including innovation agencies, technology transfer offices (TTOs), research and technology organisations, business incubators, etc.

Country characteristics and the policy mix

Evidence of innovation policies for knowledge transfer across the OECD from the EC-OECD STIP Compass database, shows that there are significant differences across countries in the relative importance given to each, in terms of budget, target groups, eligibility criteria, time horizon and implementation.

Structural and institutional conditions of each country, as well as industry demand for research inputs and the conditions of supply of universities and PRIs, explain a number of differences. The following factors need to be considered when evaluating a country’s policy mix:

- a) the country’s business sector, including firms’ size, sector of activity, technological capabilities, and ownership structure;
- b) the universities and PRIs, including their level of investment in research, orientation towards basic or applied science, and governance systems;
- c) countries’ general macroeconomic conditions as they influence the public resources available, the broad strategies of private firms, and the mobility of researchers.

1. Introduction

With large public investment in research and mounting budgetary pressures, governments of OECD countries have placed increasing emphasis on boosting the impact of these investments, specifically by building stronger science-industry links. Knowledge transfer is not an end in itself but an intermediate objective that contributes to better attaining the broader goals of science, innovation and, more generally, economic policies to promote more inclusive growth. These goals include, first, the diffusion of public research results to stimulate private sector innovation. Second, by transforming scientific breakthroughs into new products and services, knowledge transfer may contribute to addressing more efficiently grand societal challenges (e.g. climate change, public health, energy, food and water supply, etc.) (OECD, 2016a).

The notion of knowledge exchange or transfer refers to relationships between universities/PRI and firms that are not unidirectional and linear but rather interactive and collaborative, as it is not only universities and PRIs that are relevant to firms but also firms are an important source of knowledge for universities and PRIs. What is more, the *co-creation* of knowledge where mixed teams of researchers from universities and PRIs and industry engage in joint knowledge creation is increasingly recognised as important for strong innovation performance.

Policies to promote knowledge transfer are a subset of a country's science, technology and innovation (STI) policies, and are thus influenced by broader developments such as the increasing adoption of "mission-oriented" programmes or the development of cluster policies and "smart specialisation strategies" at the regional level. Thus, interactions between the policy instruments focussing on knowledge transfer, but also with broader innovation, economic and social policies need to be taken into account.

This paper provides an overview of the different types of policy instruments to promote knowledge transfer and discusses the interactions between policy instruments. It departs from the prevailing focus on evaluating individual instruments in isolation, which is problematic because often several policies simultaneously target the same types of actors (Cunningham et al. 2016; Flanagan et al. 2011; Martin 2016). The term "policy mix" is used to refer to the policy instruments implemented to deliver public action in this specific policy domain and their interactions.

The remainder of this paper is structured as follows. Section 2 maps the policy instruments used to support knowledge transfer and discusses recent policy trends. Section 3 focuses on the positive and negative interactions between policy instruments, and the role of country conditions in shaping policy mix choices. Section 4 provides some concluding remarks.

2. Mapping policy instruments

2.1. The diversity of policy instruments: relevant classifications

Policies commonly used across OECD countries comprise a diverse mix of financial, regulatory and "soft" instruments. Financial instruments include different kinds of economic transfers from the state to firms, universities or PRIs, on the condition that they collaborate 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, among other relevant issues. Finally, "soft" instruments include less interventionist modes of public policy focussed on facilitating relationships, mobilizing, networking, integrating and building trust.

Table 1 presents the results of a mapping exercise of the main policy instruments available to support industry-science knowledge transfer, resulting in 21 different types of policy instruments. This taxonomy builds on the existing academic literature (useful reviews are provided in Bozeman, 2000 and Kochenkova, Grimaldi and Munari, 2016), as well as on previous work of the OECD on knowledge transfer (e.g. OECD, 2002, 2003, 2013, 2017). Besides the distinction between financial, regulatory and soft instruments, other relevant criteria to classify policy instruments are the target groups, the main channel of knowledge transfer addressed, and whether the policy is a supply- or demand-side oriented instrument. The instruments shown in Table 1 do not constitute a final and closed inventory of policy instruments to promote knowledge transfer as public policies in this as in other fields are subject to change.

Table 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 licencing	Supply
5. Financial support to recruit PhDs or post-docs	Financial support for firms to recruit PhDs or post-docs, covering part of the salary.	Firms and Researchers	Researchers' mobility	Supply
6. Financial support to host industry researchers	Financial support schemes for universities to host industry researchers temporarily.	Universities/PRIs and Researchers	Researchers' mobility	Supply
7. Public procurement of technology	When firms are encouraged to collaborate with universities or PRIs to develop innovative solutions.	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 licenses, spin-offs, etc.	Universities/PRIs	Publications, spin-offs, IP licencing	Supply
11. Funding of infrastructures and intermediaries	Including technology transfer offices (TTOs), science parks, business incubators.	Universities/PRIs	IP licencing, 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 licencing, 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 mobilizing private research funds, earning income from IP licencing, 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 and to make the data freely 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 road-mapping 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 licencing	Demand/ Supply

Target groups

Policy instruments may target universities, PRIs or firms. Public policies should provide incentives for both sides to collaborate, with the aim of attenuating barriers associated to transaction costs and misalignment of expectations (Bruneel, D'Este and Salter, 2010).

The target of policies may be set below the institutional level of universities, PRIs or firms. For example, competitive funding schemes often target individual researchers, research groups or students. Policy programmes can also be targeted to a certain type of firms (e.g. start-ups, SMEs, large firms, foreign multinationals, etc.) or universities (e.g. top ranked universities, polytechnics, research universities, universities in backward regions, etc.).

Policy instruments may be generic or targeted to selected actors. Some policy instruments target the whole population, as is the case of tax-based reliefs or IP rights schemes and different types of regulations. Others focus on selected researchers/universities and/or firms (as is the case for different grant schemes that only apply to those selected).

Policy instruments and different channels of knowledge transfer

Knowledge transfer between industry and universities or PRIs occurs through a wide variety of formal and informal channels (Box 1). Formal channels can be more easily measured, but informal channels are equally important and are often a necessary condition to build up and maintain formal knowledge transfer interactions (Grimpe and Hussinger, 2013).

Acknowledging the variety of channels is important for public policy instruments to adequately support knowledge transfer and the diversity of its motivations, activities and outcomes. Individual policy instruments may focus on a single channel of knowledge transfer or address several channels jointly. Conversely, a single channel of knowledge transfer can be promoted through a mix of financial, regulatory and soft policy instruments.

Supply- vs. demand-side policy instruments

A further distinction can be made between supply-side policies that focus on supporting firms and research centres in the generation of new knowledge that may eventually lead to new products and services, and demand-side policies, which focus on stimulating the demand for innovative products, thus providing incentives for firms to innovate by reducing risks (OECD, 2011a).

In recent years, a shift towards a more demand-side focussed policy mix can be observed across OECD countries (OECD, 2016a). For example, Finland's policy mix has evolved from a more supply-driven approach towards a stronger focus on developing competences 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 (Halme et al., 2019). Likewise, the UK government has been placing more attention on the demand side, with new funding aimed at promoting collaboration of firms with universities and other initiatives such as the Konfer platform for businesses to identify potential academic partners.

Box 1. Channels of science-industry interaction

Science-industry knowledge transfer can take multiple forms that can be divided into formal and more informal channels (OECD, 2013). The different channels are often interconnected: for example, networking in conferences may later lead to collaborative research and this may lead to facility sharing.

Formal channels include the following:

- Collaborative research: This is about 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.
- Contract research: This is research commissioned to universities or PRIs by a private firm. It generally involves the creation of new knowledge per the specifications or goals of the client, and is frequently more applied than collaborative research.
- Academic consultancy: This refers to research and advisory services provided by public researchers to industry clients. It sometimes accompanies contract research or IP licencing by providing a means to transfer know-how and tacit knowledge.
- Intellectual property (IP) transactions: This refers to licensing and selling of IP generated by universities and PRIs to industry.
- Researchers' mobility: This refers to both university researchers working in industry and the reverse, including temporary assignments.
- Academic spin-offs: That is, the entrepreneurial route to commercialising knowledge developed by public research.
- Labour mobility: This refers to university graduates that join industry.

Informal channels include the following:

- Publication of public research results in scientific journals and other specialised media.
- Conferencing and networking: the interaction between public researchers and industry actors can take place in the context of formal conferences or dissemination events (e.g. expositions), but also in more informal settings (e.g. meetings of former class-mates that are employed in public research and industry sectors).
- Networking facilitated by geographic proximity: informal interactions between public research staff and industry researchers might be facilitated, for example, by the location of science parks near to university campuses, or firms' laboratories within university campuses.
- Facility sharing between industry and public research (e.g. laboratories, equipment).
- Courses and continuing education provided by universities to enterprises, and lectures at universities held by industry employees.

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

Other categorisations

The time horizon of policy instruments, i.e. whether they are oriented to short-term linkages (setting up a first contact) or forming long-term linkages (long term collaborations in research) also differs across instruments. The need to invest over the long run in building effective linkages between universities and firms is increasingly recognised (Frølund, Murray and Riedel, 2018).

Other relevant attributes to consider when evaluating policy instruments are their flexibility (i.e. there are possibilities to adapt to specific cases where justified), stability (i.e. actors can rely on the instrument being available to them as specified), cost efficiency, and operational complexity.

2.2. Multi-level governance of the policy mix

Different levels of governance intervene in designing and implementing policies to promote knowledge transfer, including the national, regional and supra-national levels. In addition to policies designed at national level, regional governments are increasingly active in promoting science-industry links, complementing national government initiatives in various ways, but also adding an additional element of complexity to the policy mix. In recent years, regional governments are becoming increasingly involved in knowledge transfer policies, as universities and science-industry links are considered as key drivers of regional development (OECD, 2017). In addition, some policies developed at supra-national also target knowledge transfer, complementing those developed at national or regional levels. The most evident case is the European Union, which has various policy instruments to support knowledge transfer such as large funding schemes for collaborative research projects, mobility grants for researchers, support for entrepreneurship, knowledge and innovation communities, and support for industrial PhD programmes, among others. Likewise, the World Trade Organisation has had a strong influence over national intellectual property rights regimes, through the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).

Beyond the government level, policies to foster knowledge transfer are also designed and implemented at the institutional level (i.e. by public universities and research institutes themselves). Over the last decades universities and PRIs have received more autonomy across the OECD (Borowiecki and Paunov, 2018), allowing them to deploy their own support programmes for knowledge transfer, including specific grant schemes, incentives to researchers, and support for patenting, on top of those offered across the board by the national or regional governments. This allows for a wide variety of approaches to promote knowledge transfer across different universities and PRIs.

Moreover, governments rely on different kinds of “intermediary organisations” to implement knowledge transfer policies, including innovation agencies, technology transfer offices (TTOs), research and technology organisations, business incubators, etc. (Clayton, Feldman and Lowe, 2018; OECD, 2013). 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. (Geuna and Muscio, 2009; OECD, 2013). These institutional settings often play a transformative role in framing the conditions for knowledge transfer between industry and science. Intermediary organisations differ in their size, mission, activities, ownership, and funding structure (Russo et al., 2018). Some are autonomous agencies tasked with promoting knowledge transfer and innovation more generally while others are established as units of a specific university, as is often the case of TTOs and science parks. Over the years, OECD countries have developed a complex network of intermediary organisations to promote knowledge transfer, and they continue to experiment with new institutional models.

2.3. Trends in policy instruments

Policy instruments are not static but change over time. This section discusses important changes from policy learning as a result of past failures in building effective knowledge exchange and the impacts of the digital transformation. It also discusses two developments: greater emphasis on co-creation and global research networks.

Policy learning

Policy instruments have changed in response to policy learning on a number of fronts. Importantly, there is increased awareness that encouraging patenting by research institutions is not necessarily a source of enhanced industry-science knowledge transfer. Such incentive schemes may lead to wasteful investments in patent applications that ultimately are not taken up by industry. Instead, much more emphasis is now placed on policies to encourage mobility of individuals between industry and science and in building effective knowledge collaboration. Recent policies to support academic spin-offs are increasingly focusing on projects demonstrating higher potential, rather than supporting the creation as many spin-offs. This resulted from experiencing a number of failures. There is also increased awareness that knowledge transfer instruments need to be adapted to sectors that have traditionally had fewer connections with industry and to research institutions that have no connections with industry to build effective ties.

Digital transformation

Current global trends that are driving the reform of knowledge transfer policies include the digital transformation, which increases the need for industry-science collaborations due to the increasing complexity of innovation (Guellec and Paunov, 2019). The digital transformation also offers new opportunities for collaboration (notably digital platforms).

The digital transformation is changing the way that economic interactions and business models are organised. New forms of open innovation have emerged including more intense collaborations between firms and universities or PRIs than in the past, through new practices including 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 to engage the public in addressing social needs and accelerate innovation. Against this variety of digital platforms to connect science with industry, a number of open questions emerge: To what extent and under which conditions do they create opportunities for innovation and for whom? How can scientists working at public research organisations be motivated by their institutions to participate further in these platforms? How should technology transfer offices of public research organisations interact with these digital platforms? Is there a need for additional public policy support?

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 the 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 (a more detailed discussion is provided in OECD, 2019). However, physical spaces and intermediaries will remain critical to build trust: digital platforms can only complement, but not replace, human interactions.

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, the "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, compared to a simple process of knowledge transfer, as knowledge is jointly developed through shared facilities and mixed teams.

One way to promote co-creation is the development of joint research labs. Governments of OECD countries are increasingly supporting the development of joint research laboratories through public-private partnerships, which allow universities, PRIs and firms to share resources and risks by engaging in long-term joint research activities (Frølund, Murray and Riedel, 2018).

Several OECD countries have launched new policy programmes to support knowledge co-creation. A relevant example is the Catapult programme in the UK, launched in 2015 by Innovate UK. The Catapult centres bring together businesses, scientists and engineers to work on late-stage R&D in strategic fields (Kerry and Danson, 2016). To date 10 Catapults have been established, each specializing in different industries/technologies (Cell and Gene Therapy; Compound Semiconductor Applications; Digital; Energy Systems; Future Cities; High Value Manufacturing; Medicines Discovery; Offshore Renewable Energy; Satellite Applications; Transport Systems). Each Catapult has several physical centres spread across the UK, but working modes differ (MacAulay, 2017).

Portugal's collaborative laboratories (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 between 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.

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. Such 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.

The Industry-University Cooperative Research Centres programme of the National Science Foundation (NSF) in the United States represents an early example of this policy approach. Launched in the mid-1970s and still active today, the programme develops long-term partnerships among industry, academe, and government. Selected centres receive an initial

investment from the NSF and are later mainly supported by the industry partners. Another long-standing initiative worth mentioning is the Christian Doppler Research Association programme, which has been operating in Austria since 1995 to develop public-private partnerships for application-oriented basic research (Harms, 2018).

Global research networks

Knowledge transfer policies across OECD countries are embracing a stronger international scope in order to connect with global innovation networks and to build the necessary critical mass to deal with grand societal challenges, such as climate change. For instance, Japan's Science and Technology Research Partnership for Sustainable Development (SATREPS) funds research cooperation in science and technology between Japan and developing countries aimed at developing new knowledge and technologies that help addressing global issues, such as climate change, disaster prevention or public health.

In addition, new policy approaches are emerging to 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 (OECD, 2011b).

More recently, some countries have also launched dedicated programmes to attract international universities and PRIs to establish new research centres locally in collaboration with national universities and firms. Similar to the case of incentives to attract foreign direct investments from multinational corporations that generate spillovers on local firms, the expectation is that attracting "world-class" universities or PRIs will enhance the country's science base and improve science-industry links.

Some pioneering examples are the cases of Georgia Tech in France and MIT in the UK. The first campus of Georgia Tech outside the US was established in the early 1990s in Lorraine, France, with financial support from the French government. Although initially focused on graduate education and research, with time the campus increased its engagement with local industry to foster knowledge transfer (Schmid, Kolesnikov and Youtie, 2017). For example, in 2014 the Lafayette Institute was launched within the campus to stimulate commercialisation of technologies developed in the region, providing proof-of-concept services and legal and business advice. In the UK, the government financed a partnership between MIT and Cambridge University in 2000 aimed at developing and implementing innovative approaches for knowledge transfer between the academic and industry sectors, based on the so-called "Knowledge Integration Community" model (Acworth, 2008).

More recently, in Portugal, the International Partnership Programme (IPP) was developed in 2006 with three US research universities (MIT, Carnegie Mellon University and the University of Texas at Austin), with the aim of enhancing the industrial orientation of Portuguese universities' graduate programmes and providing opportunities for doctoral students and early career researchers to engage in industry-relevant projects (Horta and Patrício, 2016). In this context several initiatives have been implemented to support academic entrepreneurship and technology transfer, such as the Building Global Innovators programme created in 2010 by MIT in partnership with ISCTE-Lisbon University Institute.

In Singapore, the government's Campus for Research Excellence and Technological Enterprise (CREATE) programme, launched in 2006, has established partnerships with ten international universities (including MIT, Cambridge, and UC Berkeley, among others) to establish new research centres closely aligned with the national economic development

strategy (Youtie et al., 2017). Some of these foreign universities have created specific programmes to promote technology commercialisation in the country, such as the Singapore-MIT Innovation Centre, which provides grants to researchers for the development of prototypes and proof-of-concept work, and links researcher to local mentors to provide commercialisation guidance and access to relevant networks.

The International Centres of Excellence programme in Chile, launched in 2009, has provided public funding to eight international universities and PRIs (UC Davis, University of Queensland and Fraunhofer Institute, among others) to create new R&D centres in Chile that collaborate intensively with local firms in relevant industries. By bringing into the country foreign research institutions with demonstrated experience in linking with industry and commercializing technology, the aim was to trigger a systemic change in the national innovation system (Klerkx and Guimón, 2017). Some of the centres have developed new intermediary institutions to promote technology transfer, such as the Research to Business Catalyst (R2B) programme of UC Davis Chile, which provides support to start-ups including legal advice, access to venture capital, mentoring, and access to research labs and equipment.

3. Evaluating the policy mix and assessing the interaction between policy instruments

Beyond the *composition* of the policy mix, it is important to assess the *interactions* (both positive and negative) between its elements, the evolving institutional architectures, and the different trajectories of policy learning and change depending on country conditions. This section looks at the interactions and combined effects of policy instruments, the coherence of the policy mix and how country contexts affect policy mix choices.

The choice of a policy mix is not the simple result of one-off optimisation decisions subject to a budget constraint, because the cost-benefit structure of different combinations of policy instruments is highly uncertain and context-specific. Moreover, policy mixes develop incrementally over many years as path-dependent outcomes influenced by previous policy choices and by different interest groups. Thus, policy mixes reflect complex social relations, changing rationales, and historical dynamics of government intervention. As such, the analysis of policy mixes is an extremely complex task and any attempt to search for the optimal policy mix should be avoided.

3.1. Assessing interactions between policy instruments

Different kinds of positive and negative interactions may arise when policy instruments are combined in a policy mix (Table 2).

Table 2. Types of interactions between 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, Sánchez and Pontón, 2019) 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 to create a new company or hold a second post, leading 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 the 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 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, the Government of Canada announced in 2018 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.

Positive interactions

The combination of several policy instruments may increase their individual impacts. Such positive interactions may occur in the form of precondition, facilitation or synergy. *Precondition* effects imply that, besides the combination of policy instruments, it is also important to consider the sequence whereby they are introduced. For example, a precondition to the implementation of policy instruments that provide financial support to academic spinoffs is to ensure that university employment regulations do not act as a barrier. In Colombia, for example, 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 to create a new company or hold a second post, leading to the enactment of a new law in 2017 (Botero, Sánchez and Pontón, 2019). A more careful ex-ante assessment of this precondition would have improved the impact of the policy mix.

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. In the UK, the so-called Lambert toolkit provides guidelines and model contracts for the management of IP in collaborative research projects between universities and industry. Likewise, in 2015 the Japanese government launched the “Guidelines for Intellectual Property Management in Government-commissioned Research and Development” to support the implementation of the Japanese version of the Bayh-Doyle Act dating back to 1999.

Finally, a *synergy* will occur, for example, when two different grant programmes offer funding for different activities or focus on different stages of the commercialisation cycle. A single research project can benefit from being funded by different sources, with each source funding different elements (e.g. personnel, equipment, etc.) or simply because the amount needed for the whole project is higher than what a single source can provide. Obtaining funding from one source, even a small amount, may be used as a ‘quality signal’ to leverage funding from other private or public sources. For example, Lanahan and Feldman (2015) discuss how 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 State level. This case also illustrates the positive interactions of complementary policy instruments across different levels of government.

Scattered evidence from evaluation studies point to different possible synergies between policy instruments. Some have found that grants for collaborative R&D projects between universities and firms will result in more joint projects if combined with policies that promote exchange of post-graduate students to gain experience of project management in an industrial context (Cunningham and Gök, 2016). Similarly, the development of infrastructure and intermediary organisations for knowledge transfer (i.e. incubators, science parks, TTOs) has more impact if accompanied by other regulatory and financial instruments. For example, a recent OECD review of innovation policies in Lithuania argued that the development of science parks is more efficient if combined with reforms in universities’ regulations for technology transfer (OECD, 2016c). With regard to financial policy instruments, business incubators work better if accompanied by financial support to provide early stage funding for entrepreneurs, for example through public venture capital funds. This is especially important in laggard countries where the business environment is weak and financial markets are underdeveloped. In the absence of such complementary policies, science parks often become pure real estate ventures with unsustainable financials, as discussed in a World Bank review of university-industry collaboration in Sri Lanka (Larsen et al., 2016).

The combination of demand and supply side measures may also lead to synergies (Guerzoni and Raiteri, 2015), but the evidence available is limited (Cunningham et al., 2016). In line with TIP work on systems innovation (OECD, 2015), Kivimaa and Kern (2016) have emphasised that policy mixes to address grand societal challenges (such as the transition to renewable energy) will be more efficient if support to the ‘creation’ of new technologies is combined with measures to facilitate structural change and shift consumer demand to new and more sustainable products.

In view of positive interactions, several policy instruments are often grouped together under one broader initiative or policy programme. For example, “cluster programmes” frequently group together several policy instruments to foster knowledge transfer, including financial support schemes to promote collaboration in innovation and soft instruments such as networking events, in addition to policy instruments belonging to other domains such as joint international promotion and export support.

Negative interactions

Negative interactions between policy instruments for knowledge transfer also need consideration. For example, there might be a *contradiction* between policy initiatives that aim at providing incentives for inventors by enhancing the IP rights regime, and those that aim to foster knowledge sharing through open access and open data (Herstad et al., 2010).

In addition to possible contradictions, negative interactions can derive from the *complexity* of using too many policy instruments simultaneously. In particular, the coexistence of different financial instruments targeting simultaneously the same types of actors can create confusion and result in higher administrative costs. Moreover, when similar financial instruments are offered both by the national and the regional governments, this might lead to undesired situations where the same collaborative project is funded twice. The proliferation of public support programmes at different levels can lead to inconsistencies, bureaucratic and political conflict, and lack of consensus when setting priorities.

In addition to national-regional coordination, some supranational organisations have developed innovation strategies and policy instruments that complement those deployed by their member countries, as discussed in Section 2.1. Synergies with those supra-national policy instruments are of course critical. For example, the National Innovation Agency in Portugal has adapted its research funding schemes to better integrate with European funding programmes, by focussing on the final stages of the innovation cycle such as pilot projects (Caldeira, 2017).

More at the horizontal policy level, the challenge is that the responsibility for the design and implementation of public policies in support of knowledge transfer is often scattered across different ministries, notably, ministries of science and innovation, education, the economy, health as well as ministries of finance. This leads to complex systems of governance that require effective inter-ministerial co-ordination. In particular, the co-ordination between higher education and research policies is a frequent concern across many countries, as is the co-ordination of research and innovation policies.

Besides those multi-level governance issues, a key concern relates to the total number of policy instruments available and the overall complexity of the policy mix. Using too many policy instruments can lead to higher administrative costs for the government and confusion for target firms/universities. Indeed, the policy mix may improve by adding complementary policy instruments, but only up to a certain point (Braathen, 2007; OECD, 2010). 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, may lead to over-complex and incoherent policy mixes. For example, in view of the vast and complicated array of programmes in place to support business innovation, the Government of Canada announced in 2018 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.

Similarly, the development of new intermediary organisations for knowledge transfer might create an overly complex system. For example, the development of regional TTOs, which provide services to several universities and PRIs, may facilitate knowledge transfer by building the necessary critical mass to provide professional services across a range of industries and knowledge transfer services. However, the diversity of technology transfer institutions (TTOs from universities, regional/sectoral TTOs, private organisations, etc.), when combined with the lack of a coherent information system, increases the complexity of the system for different stakeholders (research groups, firms, etc.) and may lead to coordination-failures, as discussed in the OECD review of innovation policies in France (OECD, 2014a).

Moreover, there may be negative interactions between regulatory instruments and efforts to build new infrastructure for knowledge transfer. For example, the development of TTOs will not be efficient if career incentives for university researchers continue to focus only on

publications or if university employment regulations hamper spin-offs by prohibiting academics from holding a second post, as it was found in the OECD review of innovation policies in Colombia (OECD, 2014b).

Policy instruments that focus on a specific channel of knowledge transfer may exert a negative effect over other alternative channels. For example, an excessive emphasis given to technology commercialisation through patent transactions can work in detriment of other modes of knowledge transfer such as R&D collaboration, contracting and two-way mobility of researchers, as suggested in the OECD review of innovation policies in Malaysia (OECD, 2016d). Thus, it is important to seek for a balanced use of various policy instruments targeting alternative channels for knowledge transfer.

Policy makers' choice of performance indicators to evaluate intermediary organisations (such as number of spin-offs, patent licencing contracts, research contracts, or joint research projects) can lead to undesirable effects if performance indicators are not well aligned with policy objectives or if indicators focus only on a few channels of knowledge transfer just because they are easier to measure (Russo et al., 2018). For example, Gulbrandsen and Rasmussen (2012) found that using the number of spin-offs as a performance indicator for technology transfer offices in Norway led to the adverse effect of pushing them to launch as many firms and as fast as possible, even if their survival chances were low. Other authors have warned that the frequent practice of evaluating TTOs based on the revenues they generate may slow down the dissemination of knowledge and inhibit other more open forms of knowledge transfer (Litan, Mitchell and Reedyet, 2007). Therefore, it is important to reflect further on how to design performance indicators that better align intermediary organisations with policy objectives.

More broadly, an increasing pressure on universities to foster commercialisation and industry engagement may create conflicts with the spheres of research and teaching, which calls for policy frameworks that enhance the integration of those three missions of universities (OECD, 2017). Besides the opportunity cost in terms of attention being diverted away from teaching and research, other potential risks that policy-makers should be aware of include the privatisation of public research outputs and the unethical behaviour of researchers due to conflicts of interest (Arza, 2010).

Interactions with other policy domains

Policies to promote knowledge transfer are a subset of a country's overall science and innovation policies, and are thus influenced by broader developments such as the increasing adoption of "mission-oriented" programmes or the development of cluster policies and "smart specialisation strategies" at the regional level. Thus, it is important to consider not only interactions between the policy instruments focussing on knowledge transfer, but also other science and innovation policy instruments that do not aim directly at promoting knowledge transfer are also important even if their influence is more indirect.

Broader social and economic policies also shape the scope of knowledge transfer. These include all policies that affect what innovations are undertaken, including health, energy and environmental policies as they influence the demands for certain types of technologies (Caiazza, 2016). Policies that affect the business framework conditions are also important, in particular labour market policies, education and training policies, financial market regulations, competition policy, the international trade regime, etc. For example, labour market policies (such as the characteristics of work contracts and the regulation of unemployment and retirement benefits) influence the mobility of researchers, an important channel of knowledge transfer. In particular, the need for more temporary mobility between

research and industry and vice versa is often made difficult by the nature of labour contracts at research institutions which, in turn, are a reflection of general labour market contracts in the public sector (for countries where such contracts apply to researchers).

Implications for policy evaluations

These interactions suggests that, when it comes to evaluating the success of policy instruments, it is important to take into account the entire policy mix, as several policy instruments simultaneously target (or affect) the same actors, and thus observed outcomes are the result of the combined effect of several policies. So far, typical evaluations focus on individual policy instruments in isolation, without considering how different instruments interact within a policy mix (Borrás and Laatsit, 2018; Edler et al., 2012). 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 (Edler et al., 2008; Magro and Wilson, 2013). This could be done by more systematic evaluations of entire policy mixes and by introducing, within the templates used to evaluate individual policy instruments, a specific section that focusses on their interaction with the broader policy mix.

At the time of introducing a new policy instrument, it is important to link up with existing policy mixes and implementation structures. An ex-ante evaluation of the policy mix may help improve policy design by avoiding negative interactions between policy instruments. For example, in Greece, at the time of launching a new public venture capital fund to promote spin-offs in 2017, 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 (Spilioti, Gongolidis and Gypakis, 2019).

3.2. Evidence on the policy mix across countries: similarities and differences

An analysis of the STIP Compass database (Box 2) shows that OECD countries tend to use the same type of policy instruments, in line with previous studies (e.g. Veugelers, 2015). This convergence may be due to peer learning and “policy diffusion”, including policy recommendations by international organisations and information exchange among countries (Knill, 2005).

Box 2. Analysing knowledge transfer policies through the STIP Compass database

The EC/OECD Science, Technology and Innovation Policy (STIP) Compass Database (<https://stip.oecd.org/stip.html>) collects country responses to a biannual STI policy survey. The analysis conducted for this paper focused on country responses under Section D of the questionnaire (titled “public-private knowledge transfer and linkages”). This section collects policy initiatives grouped under six themes, each corresponding to a specific question in the questionnaire: 1) Transfer and linkages strategies; 2) Collaborative research; 3) Cluster policies; 4) Commercialisation of public research results; 5) Inter-sectoral mobility; and 6) IP rights in public research. The data for this analysis was extracted on July 2018 (referring to the 2017 edition of the questionnaire) and comprised 820 policy initiatives related to knowledge transfer across 48 countries.

Source: <https://stip.oecd.org/stip.html>

However, the STIP Compass database also shows significant differences across countries in the relative importance given to 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, monitoring methods, etc.). The divergence of policy mixes can be associated with the specific structural and institutional characteristics of countries, as discussed in previous research (e.g. Seppo, Roigas and Varblane, 2014).

To provide an example of those differences, 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 3). 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. Likewise, recent policy reports show how other financial policy instruments that influence science-industry knowledge transfer, such as performance based funding of universities (Borowiecki and Paunov, 2018; Debackere et al., 2018) and mission-oriented research funding (European Commission, 2018), have become increasingly popular albeit with a large variation of design and implementation practices across countries.

This “divergence within convergence” can also be observed across policy instruments targeting other channels for knowledge transfer. For example, when it comes to promoting industry-academia mobility of researchers, some countries focus on mobility from firms to universities, others from universities to firms, and others on both simultaneously (Table 4). Only some programmes offer financial subsidies, while others are limited to providing guidelines and networking services. Among those providing financial subsidies, the proportion of the salary subsidised and the average duration of the subsidy also differ.

Table 3. Grant programmes for public research requiring collaboration with industry partners129 policy initiatives from 34 countries in 2017¹

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, EUR²	
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 beneficiaries³	
Established researchers	44%
Undergraduate/master students	14%
Post-doctoral researchers	28%
PhD students	33%
Higher education institutes	57%
Public research institutes	53%
Type of activities funded³	
Basic research	46%
Applied research	92%
Experimental development	37%
Selection criteria³	
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, the People's Republic of China, Colombia, Costa Rica, Czech Republic, Germany, Finland, France, Greece, Hungary, Ireland, Latvia, Lithuania, Malta, Mexico, Morocco, Netherlands, Norway, Peru, Poland, Portugal, Russia, Slovenia, Sweden, Switzerland, Thailand, Turkey and UK.

² Only for this question, the sample size is 103 because 26 observations with missing answer are excluded.

³ Notice that the sum is not 100% because each initiative may have several different beneficiaries, eligibility criteria, and type of activities funded.

Source: STIP Compass database.

Table 4. 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	3 rd 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

Source: STIP Compass database (retrieved on July 2018), considering only policy initiatives active in 2017. Complemented with information provided by country representatives to TIP.

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 5). Many focus on providing those incentives to SMEs, on the condition that they use it to contract services from a certified knowledge provider from a university or PRI.

Table 5. Innovation voucher programmes that support the acquisition by firms of specialised services from universities and PRIs: selected examples

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: STIP Compass database (retrieved on July 2018), considering only policy initiatives active in 2017. Complemented with information provided by country representatives to TIP.

On the regulatory front, most countries have reformed their IP regimes in order to stimulate academic patenting, but the directions and rhythms of these reforms have varied substantially across countries (Martinez and Sterzi, 2018; Weckowska et al., 2018). While most countries have transferred ownership of publicly-funded research results from the state (government) to the (public or private) agent performing the research, where countries (and institutions within countries) differ is in the allocation of ownership among performing agents (research institution vs. individual researcher) (Borowiecki and Paunov, 2018).

With regard to intermediary organisations, comparative studies reveal a large variety of TTOs with respect to their size, their institutional configuration and their focus on a specific set of services (Bengtsson, 2017; Cartaxo and Godinho, 2017; Cesaroni and Piccaluga, 2016; Schoen, de la Potterie and Henkel, 2014). TTOs are usually ascribed to individual universities or PRIs, although some operate in a more autonomous manner, as non-for-profit associations or even as self-sustainable public-private partnerships. In recent years, new models involving regional or sectoral associative structures have also emerged, often based on the association of several universities and PRIs that pool services to improve efficiency and quality (Table 6).

Table 6. Examples of off-campus TTOs established through consortia of universities/PRI

Country	Year launched	Scope	Brief description
Belgium	2014	Regional	TTO Flanders is a joint initiative of the TTOs of the 5 Flemish Universities. The TTO aims to be a unique point of contact for industry and to increase the international orientation of technology transfer, notably via its online portal.
Chile	2016	Sectoral	Three "Technology transfer hubs" were created in priority sectors (agriculture, health, and industrial production and energy). The hubs are decentralised entities whose shareholders are a group of at least six universities/PRI. Hubs complement individual TTOs of participating universities, e.g. by centralizing some functions such as international commercialisation of technologies.
Colombia	2013	Regional	Six regional TTOs have been created building alliances between universities, research centres and firms in order to build sufficient critical mass to operate more efficiently and to be able to provide high quality specialist services.
France	2011	Regional	A total of 14 "transfer acceleration companies" (SATTs) have been created to co-ordinate the TTOs of universities/PRI within the regions. They have pooled certain functions of their member organisations (e.g. IP management) and developed new activities (e.g. innovation development).
Ireland	2013	National	A national TTO called Knowledge Transfer Ireland (KTI) was established in 2013 as a partnership between Enterprise Ireland and the Irish Universities Association, to complement existing in-campus TTOs with a more centralised structure to promote knowledge transfer. Among other activities, KTI has created a web for companies to explore the research resources available throughout the country.
New Zealand	2011	National	The Kiwi Innovation Network (Kiwinet) is a consortium of 16 universities and PRIs that aim to share resources and provide common services to leverage the country's technology transfer capabilities.
Norway	2015	Regional	The Bergen Teknologioverføring (BTO) was set up in 2005 to serve all universities and PRIs in the region of Bergen. Over time, other regions of the country have also established joint TTOs or merged existing ones to encourage critical mass and specialised expertise.

Source: STIP Compass database (retrieved on July 2018), considering only policy initiatives active in 2017. Complemented with information provided by country representatives to TIP.

This set of examples illustrates the variation that appears across countries; 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. The following section explores further the kind of country-specific factors that may influence the choice of policy mixes.

3.3. Searching for a coherent policy mix adapted to country contexts

Country differences play a role when it comes to evaluating the policy mix, as actors and institutions differ along a number of dimensions. The most appropriate channels and policy mixes to promote knowledge transfer depend on a country's level of socio-economic development, size, R&D intensity, and other structural and institutional factors.

The following three factors are particularly important when evaluating a country's policy mix: i) the characteristics of the business sector, ii) the characteristics of HEIs and PRIs and of their research, and iii) macroeconomic conditions.

Characteristics of the business sector

Knowledge transfer depends on the characteristics of the country's business sector, specifically firms' size, sector of activity, technological capabilities, and ownership structure. First, the challenges faced by SMEs are different from those of larger firms. 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. Intermediary organisations and industry/regional associations may also help SMEs access global markets that otherwise would not be possible. SMEs are of course diverse, and also include dynamic technology-based start-ups.

Second, the mechanisms for knowledge transfer in high tech industries are quite different from those in low tech industries and services (Bekkers and Bodas Freitas, 2008; Paunov, Planes-Satorra and Moriguchi, 2017; Perkmann et al., 2013). For example, the pharmaceutical and chemical industries rely more extensively than other sectors on technology transfer through patent transactions, drawing heavily on scientific research in the fields of life science, medical science and chemistry (Paunov, Planes-Satorra and Moriguchi, 2017). In contrast, firms operating in services sectors tend to rely to a large extent on informal channels for linking with universities, with a focus on tacit knowledge, recombination of existing knowledge, and specific problem-solving (Johnston and Huggins, 2017).

Third, different policy approaches may be necessary to support knowledge transfer towards firms with weak technological capabilities. For example, innovation vouchers and technology extension services may be useful policy instruments to initiate a virtuous circle between the demand for innovation and the offer of innovative solutions in environments where there is a lack of formalised demand for innovation. Where such connections exist, those policies may have little additional effects while policies aimed at building effective co-creation may have a better grounding.

Finally, the ownership characteristics of firms are also important to understand their innovative behaviour and the potential of different policy instruments to promote knowledge transfer. In particular, a better understanding of how foreign-owned multinational subsidiaries collaborate with universities in the host country may offer insights to shape knowledge transfer policies (Guimón and Salazar-Elena, 2015). The same applies to state-owned enterprises, the collaborative behaviour of which may be influenced more directly by government prescriptions (Tonurist, 2015).

Characteristics of universities and PRIs

Differences in the characteristics of universities and PRIs should also be considered when analysing the policy mix for knowledge transfer. While there is a trend towards greater autonomy and increasing use of performance-based systems of public funding, the relative importance and the division of labour between universities and PRIs, and between different kinds of universities, varies substantially across OECD countries. Some countries, such as Germany and Portugal, are characterised by institutional configurations where research universities (driven toward excellence but under mounting pressure to also produce useful research-based innovation) coexist with universities of applied research or ‘polytechnics’ (which engage in practice-based research and professional development, with close relationships with local communities and SMEs, in particular through innovation).

There also tends to be a strong concentration of universities within countries, with many smaller universities and a few very large institutions that concentrate the bulk of academic research. The disciplinary structure of universities and PRIs and their research quality are critical factors to understand the channels through which they link with industry (Paunov, Planes-Satorra and Moriguchi, 2017). 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.

Macroeconomic conditions

It is also necessary to consider the general macroeconomic conditions when analysing the policy mix, as these will influence the public resources available, the broad strategies of private firms, and the mobility of researchers. Given the long-term nature of innovation processes, a stable policy environment is invaluable, providing continuous public support independently of political and financial cycles. But this is a daunting challenge in many countries, particularly in the event of severe crises. For example, following a deep economic depression in recent years, Greece has faced challenges that affect knowledge transfer directly, such as the emigration of high-quality researchers, the rise of corporate taxes that affect entrepreneurship and the constraints to state support to innovation due to financial austerity measures (Spilioti, Gongolidis and Gypakis, 2019). This has also been the case in other Southern European countries such as Italy, Portugal and Spain, leading to a growing divergence in innovation performance between advanced and catching-up European countries during the recent economic downturn (Archibugi and Filippetti, 2011; Cruz-Castro and Sanz-Menéndez, 2016).

4. Conclusions

This paper provides a conceptual framework to analyse the policy mix for knowledge transfer by mapping policy instruments; assessing interactions between different policy instruments; and considering the influence of countries' institutional and structural conditions. The combination of several policy instruments may create synergies but may also reduce the success of individual instruments. To have maximum synergies and avoid negative interactions of the policy mix, existing policy instruments should be mapped and the implications of different combinations of policy instruments evaluated. This requires moving away from assessing the impacts of single instruments in isolation. Such evaluations will be valuable at the moment of deciding whether and, if so, how to introduce new policy instruments to the existing policy mix.

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