Chapter 5
The Policy Mix to Promote University-Industry Knowledge Transfer: A Conceptual Framework

José Guimón and Caroline Paunov

Abstract Countries deploy a variety of policy instruments to promote university-industry knowledge transfer. 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. This chapter presents a conceptual framework to map policy instruments for knowledge transfer and assess the interactions between them. Positive interactions occur, for example, when a new grant scheme to support spin-offs is accompanied by the adoption of more flexible regulations regarding the participation of university professors in firms, leading to a stronger combined impact. In contrast, negative interactions are associated with potential contradictions between policy instruments or with the coexistence of various policies targeting simultaneously the same types of actors, which increases complexity, creates confusion and results in higher administrative costs. The conceptual framework developed in this chapter also aims to explain how the choice of policy instruments is influenced by national contexts and broader international trends. This framework is a useful tool for those involved in the design and evaluation of university-industry knowledge transfer policies, while offering a broad point of departure for future research.

Keywords Policy-mix · Policy instrument · Knowledge transfer · Co-creation · Public research · Intermediary organizations · Evaluation · Interaction · Intellectual property · Collaboration · Spin-offs

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5.1 Introduction

With large public investment in research and mounting budgetary pressures, policy-makers have placed increasing emphasis on boosting the impact of these investments, specifically by building stronger university-industry links. The notion of knowledge transfer or exchange refers to relationships between universities and firms that are not unidirectional and linear but rather interactive and collaborative, as it is not only universities that are relevant to firms but also firms are an important source of knowledge for universities. What is more, the *co-creation* of knowledge where mixed teams of researchers from universities and industry engage in joint knowledge creation is increasingly recognised as important for strong innovation performance (De Silva & Rossi, 2018; Koschatzky & Stahlecker, 2016).

This chapter develops a conceptual framework to analyse the policy mix for knowledge transfer. We use the term "policy mix" to refer to the combination of policy instruments implemented to deliver public action in a specific policy domain and their interactions. The study was developed within the context of our work for the knowledge transfer project (2017–2018) of the Technology and Innovation Policy (TIP) Working Party of the Organization for Economic Cooperation and Development (OECD).[1]

In recent years, the policy mix concept has been widely adopted in innovation studies, following the influential contribution of Flanagan et al. (2011). Borrás and Edquist (2013) rely on the policy mix concept to discuss the critical issue of how to choose policy instruments in a specific territory and at a given point in time. Other authors have used the policy mix concept to assess the complex interplay between different levels of government in the field of innovation policy (Magro & Wilson, 2019). A central argument behind the literature on innovation policy mixes is that the prevailing focus on designing and evaluating individual instruments in isolation is problematic, because often several policy instruments simultaneously target the same types of actors and policy objectives (Cunningham et al., 2016) and "each new policy instrument will clearly interact with and affect existing policy instruments in a complex and often unpredictable manner" (Martin, 2016: p. 167). Along these lines, Rogge and Reichardt (2016) propose an analytical framework to evaluate policy mixes based on various characteristics such as consistency of its elements, coherence of processes, credibility and comprehensiveness.

Rather than considering the entire innovation policy mix, this chapter focuses on policies to promote knowledge transfer. As sketched in Fig. 5.1, the proposed conceptual framework entails *mapping* the different types of policy instruments and assessing the *interactions* between them. In the following section, we map policy instruments by classifying them according to different criteria, including: (i) whether they are financial, regulatory or soft instruments; (ii) whether they target primarily firms/industry, researchers or universities; (iii) the type of knowledge

[1] The full results of this Project, including various policy papers, workshop reports and national case studies, are available at: http://oe.cd/colab

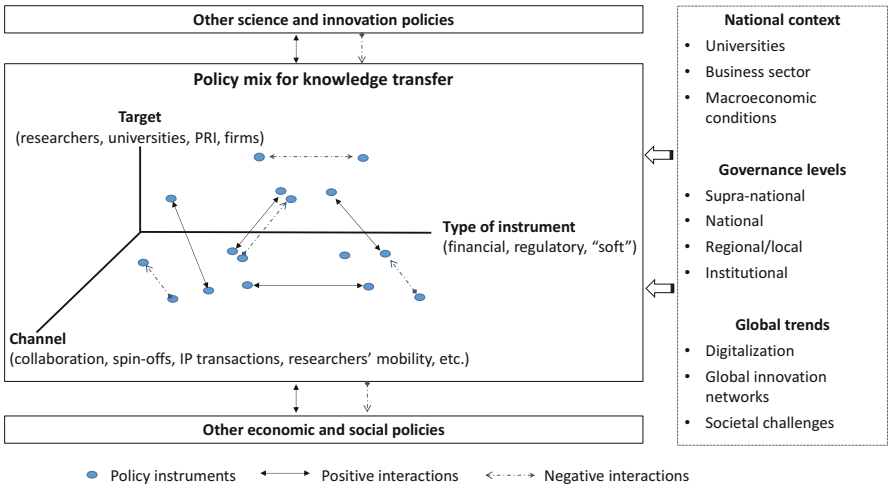

Fig. 5.1 Conceptual framework

transfer channels being addressed; and (iv) the instruments' supply- or demand-side orientation. In Sect. 5.3, we discuss the importance of taking into account the interactions (both positive and negative) between the policy instruments focussing on knowledge transfer. In addition, we acknowledge how the policy mix to promote knowledge transfer is also influenced by broader developments in a country's science, technology and innovation policies and by other policy domains such as labour market policies or financial regulations. Section 5.4 looks into the contextual factors that influence the policy mix, including national characteristics, multi-level governance arrangements, and global trends.

5.2 Mapping Policy Instruments

Table 5.1 presents the results of a mapping exercise of the main policy instruments available to support university-industry 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 et al., 2016), as well as on previous work of the OECD on knowledge transfer (e.g. OECD, 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. In any case, this list does 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. Moreover, the number of instruments could become shorter or longer depending on the level of granularity used for the taxonomy. An additional challenge in any attempt to classify policy

Table 5.1 A taxonomy of policy instruments to support knowledge transfer

	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, Firms	Collaboration	Supply
2. Tax incentives	Tax credits for companies that engage in collaborative research or purchase services from universities.	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, Entrepreneurs	Spin-offs	Supply
4. Grants for IP applications	Covering the costs of registration in patent offices, to encourage researchers to disclose and commercialize 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, Researchers	Researchers' mobility	Supply
6. Financial support to host industry researchers	Financial support schemes for universities to host industry researchers temporarily.	Universities, Researchers	Researchers' mobility	Supply
7. Public procurement of technology	When firms are encouraged to collaborate with universities 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.	Firms	Contracts, consulting	Demand

(continued)

Table 5.1 (continued)

	Brief description	Target groups	Main channels	Supply vs. 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, 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	Publications, spin-offs, IP licencing	Supply
11. Funding of infrastructures and intermediaries	Including technology transfer offices (TTOs), science parks, business incubators.	Universities	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, Universities	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, Universities	Spin-offs	Supply
14. Career rewards for professors and researchers	Rewards for mobilizing 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

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Table 5.1 (continued)

	Brief description	Target groups	Main channels	Supply vs. demand
15. Sabbaticals and mobility schemes	Regulations allowing sabbaticals for scientists to join industry and temporary recruitment of industry researchers.	Researchers, Universities	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, Universities	Publications	Supply
Soft instruments				
17. Awareness-raising	Outreach activities to raise awareness, including information brochures and websites, conferences and seminars.	Universities, 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, 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, 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, Firms	Collaboration, IP licencing	Demand, Supply

instruments is that they are subject to a high degree of "interpretive flexibility", because they carry "different meanings from time to time, place to place and actor to actor" (Flanagan et al., 2011: p. 706).

5.2.1 Nature of the Policy Instrument

Policies to promote university-industry knowledge transfer comprise a diverse mix of financial, regulatory and "soft" instruments, following the general classification used in Borrás and Edquist (2013). Financial instruments include different kinds of economic transfers from the state to firms or universities on the condition that they collaborate among each other. Regulatory instruments aim at providing incentives to the different parties involved in university-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.

5.2.2 Target Groups

Policy instruments may target universities 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 et al., 2010). The target of policies may be set below the institutional level of universities or firms. For example, competitive funding schemes often target individual researchers, research groups or students. Policy programmes can also be targeted to certain types 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, industries or technologies. 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 with different grant schemes that only apply to those selected).

5.2.3 Policy Instruments and Different Channels of Knowledge Transfer

The circulation of knowledge between universities and firms does not occur only through formal channels (e.g. collaborative research, contract research, provision of specialised services, IP transactions, spin-offs, etc.) but also through informal channels (e.g. publications, conferences, networking, facility sharing, etc.) (Arza, 2010; Bekkers & Bodas Freitas, 2008). Acknowledging the variety of linkages is particularly important for public policy instruments to adequately support knowledge transfer and the diversity of its motivations, activities, and outcomes. Support for more formal linkages may have lower benefits than expected if informal linkages

are weak and not supported. 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 & Hussinger, 2013). 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.

5.2.4 Supply- Versus 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 (Guerzoni & Raiteri, 2015; OECD, 2011). In recent years, a shift towards a more demand-side focussed policy mix can be observed (OECD, 2016a). For example, Halme et al. (2019) discuss how 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.

5.2.5 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 et al., 2018). Other relevant attributes to consider when evaluating policy instruments are their flexibility (i.e. 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.

5.3 Assessing the Interaction Between Policy Instruments

Beyond the *composition* of the policy mix, it is of paramount importance to assess the *interactions* between its elements. Different kinds of positive and negative interactions may arise when policy instruments are combined in a policy mix (Table 5.2). In recent years, the importance of carefully analysing these kinds of

Table 5.2 Types of interaction between policy instruments

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

interactions has been stressed in the broader literature on science and innovation policies (Cunningham et al., 2016; Flanagan et al., 2011; Martin, 2016).

5.3.1 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 instance, 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 et al., 2019). A more careful sequencing would have improved the impact of the policy mix.

Governments 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

commercialization 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 & Gök, 2016). Similarly, the development of infrastructure and intermediary organizations for knowledge transfer (i.e. incubators, science parks, TTOs) has more impact if accompanied by other regulatory and financial instruments. For example, a recent 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, 2016b). 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 & Raiteri, 2015). Moreover, Kivimaa and Kern (2016) have emphasized 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.

5.3.2 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). Moreover, 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 a review of innovation policies in Malaysia (OECD, 2016c). Thus, it is important to seek for a balanced use of various policy instruments targeting alternative channels for knowledge transfer. 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 (Laredo, 2007; Pinheiro et al., 2015). 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 privatization of public research outputs and the unethical behaviour of researchers due to conflicts of interest (Arza, 2010).

In addition to contradictions between policy instruments, negative interactions can derive from the *complexity* of using too many 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. 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 (Borrás & Edquist, 2019).

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 (Howlett & Rayner,

2013) whereby new policy programmes tend to be piled on top of one another, often 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.

Policy makers' choice of performance indicators to evaluate intermediary organizations (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 et al., 2007). Therefore, it is important to reflect further on how to design performance indicators that better align intermediary organizations with policy objectives.

5.3.3 Interactions with Other Policy Domains

Policies to promote knowledge transfer are a subset of a country's overall science and innovation policies. 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. For example, mission-oriented innovation policies, which are becoming increasingly popular around the world, have an influence over the specific technologies and industries where knowledge transfer will be prioritized. Similarly, at subnational level, the scope of knowledge transfer is strongly influenced by cluster policies and "smart specialization strategies".

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 (Williamson & Allard, 2018). 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).

5.3.4 Implications for Policy Evaluations

These interactions suggest 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 & Laatsit, 2019; 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 & 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 et al., 2019).

5.4 Contextual Factors Affecting the Policy Mix

5.4.1 National Characteristics

Previous studies suggest that countries tend to use the same type of innovation policy instruments (e.g. Veugelers, 2015), which can be attributed to "policy diffusion" and peer learning (Knill, 2005; Stone, 2004). However, there are also 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.). Regarding knowledge transfer, countries facing similar problems might opt for different solutions given their different institutional and socioeconomic structures, including their level of socio-economic development, size, R&D intensity, and other structural and institutional factors (Lepori et al., 2007; Seppo et al., 2014). The following factors are particularly important when assessing a country's policy mix: (i) characteristics of the business sector; (ii) characteristics of universities; and (iii) macroeconomic conditions.

5.4.1.1 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, although SMEs are of course very 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 & Bodas Freitas, 2008; Johnston & Huggins, 2017; Perkmann et al., 2013). 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. 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 & 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).

5.4.1.2 Characteristics of Universities

Differences in the characteristics of universities 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 (Henkel, 2005; Hicks, 2012), the division of labour between different kinds of universities varies substantially across countries. Some countries, such as

Germany and Portugal, are characterized 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). Moreover, there 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 their research quality are critical factors to understand the channels through which they link with industry (Paunov et al., 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.

5.4.1.3 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 et al., 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 (Azagra-Caro et al., 2019; Cruz-Castro & Sanz-Menéndez, 2016).

5.4.2 Multi-Level Governance

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 becoming increasingly involved in knowledge transfer policies, as university-industry links are considered key drivers of regional development (Lanahan & Feldman, 2015; Magro & Wilson, 2019). Moreover, some policies developed at

supra-national level also target knowledge transfer, complementing those developed at national or regional levels. The most evident case is the European Union, which encompasses 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 Organization 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 universities and public research institutes themselves). Over the last decades universities have received more autonomy across the world (Borowiecki & Paunov, 2018; Henkel, 2005; Paradeise et al., 2009), 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.

Furthermore, governments rely on different kinds of "intermediary organizations" to implement knowledge transfer policies, including innovation agencies, technology transfer offices (TTOs), research and technology organizations, business incubators, etc. (Clayton et al., 2018; OECD, 2013). In particular, a growing number of TTOs have been developed across the world since the mid-1990s to support different stages of the commercialization 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 & Muscio, 2009). Intermediary organizations differ in their size, mission, activities, ownership, and funding structure (Cartaxo & Godinho, 2017; Russo et al., 2018; Schoen et al., 2014). 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.

Recent contributions have also advocated for a stronger involvement of the civil society in research policy and technology transfer through 'citizen science' processes (Bonney et al., 2016) and for the adoption of flexible and open approaches to governance based on experimentation and learning (Kuhlmann et al., 2019).

5.4.3 Global Trends

Current global trends that influence the policy mix for knowledge transfer include the digital transformation, the spread of global innovation networks, and the increasing urgency to address grand societal challenges such as climate change.

5.4.3.1 Digital Transformation

The digital transformation is changing the way that economic interactions and business models are organised (Guellec & Paunov, 2018). New forms of open innovation have emerged including more intense collaborations between firms and universities than in the past, through new practices including online communities of experts, tournaments, open calls and crowdsourcing (Yoo et al., 2012; West & Lakhani, 2008). 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 influence the mechanisms for science-industry knowledge transfer and call for new policy approaches (OECD, 2019).

5.4.3.2 Global Research Networks

New policy strategies 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 needs to embrace a broad scope to ensure that the ecosystem is attractive not only for local players but also for foreign multinational enterprises (Belderbos et al., 2016; Thursby & Thursby, 2006). More recently, some countries have also launched dedicated programmes to attract international universities and public research institutes to establish new research centres locally in collaboration with national universities and firms (Guimón & Narula, 2019; Horta & Patrício, 2016). 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 public research institutes will enhance the country's science base and improve science-industry links.

5.4.3.3 Grand Societal Challenges

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. By transforming scientific breakthroughs into new products and services, knowledge transfer may contribute to addressing more efficiently grand societal challenges such as climate change, public health, energy, food and water supply, etc. (OECD, 2016a; Trencher et al., 2013). Recent studies emphasize the transformative potential of innovation policies that set the direction of change through more ambitious interventions focussing on

designated priority areas and societal challenges, where science-industry knowledge transfer can play a crucial role (Fagerberg, 2018; Kuhlmann & Rip, 2018; Mazzucato, 2011).

5.5 Conclusion

This chapter has developed a conceptual framework to analyse policy mixes for knowledge transfer by mapping policy instruments; assessing interactions between different policy instruments; and considering the influence of countries' structural conditions as well as global trends. The combination of several policy instruments may create synergies but may also reduce the success of individual instruments. To attain maximum synergies and avoid negative interactions, existing policy instruments should be mapped and the implications of different combinations of policy instruments evaluated. This requires moving away from evaluating the impact of single instruments in isolation. Broader evaluations will be valuable at the moment of deciding whether and, if so, how to introduce new policy instruments to the existing policy mix.

In any case, it needs to be stressed that the choice of a policy mix is not the simple outcome of one-off optimization 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 (Howlett & Rayner, 2013). Thus, policy mixes reflect complex social relations, changing rationales, and historical dynamics of government intervention. As such, any attempt to search for the optimal policy mix would be out of place.

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