Determinants of the university technology transfer policy-mix: A cross-national analysis of gap-funding instruments

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Abstract

University-industry technology transfer (TT) has become increasingly institutionalized and is supported by numerous reforms and initiatives at the national, regional and university levels. Most countries have implemented a policy mix involving a range of instruments to support the commercialization of research. Still, there is no systematic evidence indicating why the mix of policy instruments differs between countries. This study offers a novel cross-national investigation of the policy mix emphasizing the level of centralization and decentralization of policy instruments. We map and analyze two specific types of public instruments aimed at addressing the so-called funding gap in TT: proof of concept programs (POCs) and university-oriented seed funds (USFs). Based on a survey across 21 European countries, we find that such instruments are widely used but are organized differently depending on the level of implementation of TT practices in the country and the specific type of instrument considered. More precisely, we find a U-shaped relationship between the use of centralized gap-funding instruments and the country's implementation of TT practices. Moreover, the type of gap-funding instrument (POC or USF) moderates this relationship. We discuss the implications of our findings and suggest that the policy mix of gap-funding instruments evolve with the maturity of the national TT infrastructure.

Keywords: Cross-country analysis, gap-funding instruments, policy mix, proof of concept programs, technology transfer university seed funds.

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1. Introduction

The enhancement of knowledge transfer between public research institutions and industry has become a fundamental area for policy actions undertaken by national governments and regional authorities (Geuna and Muscio, 2009; Siegel, Veugelers, and Wright, 2007). Policy interventions have, for instance, involved legislative acts and other regulations related to intellectual property (IP) ownership and exploitation of research results (Baldini 2006; Geuna and Rossi 2011; Lissoni, 2013) and the establishment of publicly funded structures and programs to support commercialization activities (Wright et al. 2006; Rasmussen 2008; Rasmussen and Rice 2012).

Most countries have implemented a mix of public policy instruments providing financial support to technology transfer (TT) from universities and public research organizations (PROs) (Bozeman, 2000; Geuna and Rossi, 2011; Feldman et al., 2002). Such public funding instruments can potentially play a crucial role in harnessing innovation at the national and regional levels. For instance, the Small Business Innovation Research (SBIR) program in the US has been attributed a catalyzing role in transforming the US innovation environment (Keller and Block, 2013). Despite the growing number of studies analyzing the design and impact of specific public policy instruments aimed at increasing TT and university-industry links (Kochenkova et al., 2015), there is a lack of cross-national comparative research in this area (Giuri et al., 2014).

TT instruments are no longer exclusively in the hands of national authorities; increasingly, national initiatives are complemented or even substituted by regional policies and bottom-up initiatives (Lanahan, 2015; Rasmussen 2008). This trend raises questions regarding the level of centralization and decentralization of TT instruments aiming at enhancing TT activities of universities and PROs (Borrás and Edquist, 2013). Moreover, the trend calls for new perspectives and evidence on the factors that define the spatial governance of TT policies in terms of decentralization versus centralization. Decentralization is defined as the design and funding of TT instruments by government entities below the national level (i.e., regional or local authorities).

Policy instruments cannot be addressed in isolation but rather as part of a policy mix involving

different types of instruments implemented by different jurisdictions and operating in different contexts (Lanahan and Feldman, 2015). Although the selection and design of the policy instrument mix is a key topic in the innovation policy literature (Borrás and Edquist, 2013), there is no systematic evidence indicating why the mix of policy instruments differs between countries.

To address such issues, this paper maps and analyzes public instruments to support TT in Europe and compares the experiences of different countries in this area. In particular, we focus on public policies aimed at addressing the so-called funding gap, defined as the lack of private funding sources to support the transition of early-stage university technologies from the lab to the marketplace. We devote particular attention to two policy instruments oriented towards universities and PROs: proof-of-concept programs (POCs) and university seed funds (USFs).[2] We label these measures gap-funding instruments (Bradley et al., 2013; Gulbranson and Audretsch, 2008; Croce et al., 2013; Munari et al., 2014). These specific instruments were chosen because they represent relatively uniform and widely used mechanisms to enhance TT, among a variety of different policy instruments (Borrás and Edquist, 2013; Rasmussen and Sørheim, 2012). We address the following research questions:

1. *How does the level of centralization and de-centralization of gap-funding instruments vary among European countries?*
2. *What explains the level of centralization and de-centralization of gap-funding instruments in support of technology transfer*?

We use empirical evidence from a survey to 125 university Technology Transfer Office (TTO) managers, complemented by interviews with 41 TT and entrepreneurial finance experts in Europe. We identify, and investigate in greater detail, 117 gap-funding instruments across 21 European countries. In a regression analysis, we explore whether the likelihood of centralization of a gap-

[2] In this report, we refer to university-oriented proof of concept programs as programs aiming to evaluate the technical feasibility and commercial potential of early-stage technologies generated by universities and PROs. University-oriented seed funds are defined as seed and early-stage funds that have a deliberate and explicit mission to make investments in university and PRO start-ups to support TT and the commercialization of university and public research results (Munari et al., 2014).

funding instrument depends on a set of variables, including how well a country has developed its TT policies and practices (as measured by the implementation of recommended TT practices) and the type of gap-funding instrument (POC versus USF). Our analyses show a wide variety of arrangements across Europe in terms of the centralization and decentralization of gap-funding instruments. We find a curvilinear relationship between the level of centralization and the development of national TT policies and practices, with the highest level of decentralization occurring at intermediate levels of development of national TT policies and practices. This relationship, however, depends on the type of instrument.

Through our novel cross-national study of gap-funding instruments, we contribute to a better understanding of the determinants behind the policy mix adopted by different countries in support of TT (Flanagan, Uyarra, and Laranja, 2011). Our findings suggest an evolutionary interplay between the spatial dimension in terms of centralization or decentralization, a time-variant context dimension in terms of implementation of TT practices, and the specific aim of the instrument. These complex patterns provides a basis for discussing and analyzing the benefits and drawbacks of different instruments in light of specific contexts.

The rest of the paper is structured as follows. Section 2 provides a brief review of the literature, highlighting the rationale of public intervention for TT and defines the specific instruments of POC programs and USFs. Section 3 formulates our main hypotheses related to why the mix of policy instruments differs between countries. Section 4 reports the methodology of our analyses. In Section 5, we report the findings, and in the final section, we present our conclusions and policy recommendations.

2. Literature Review

2.1. The rationale and characteristics of gap-funding instruments for technology transfer

The complexity of TT between academia and industry can be ascribed to a set of obstacles and market inefficiencies at the intersection of these two fields (Van Dierdonck and Debackere, 1988;

Salmenkaita and Salo, 2002; Siegel et al., 2004; Bruneel et al., 2010; Tartari et al., 2012; Villani 2013). The so-called funding gap is often referred to as the most significant obstacle among market inefficiencies (Salmenkaita and Salo, 2002; Lockett and Wright, 2005; Munari and Toschi, 2011). This gap describes the lack of available private sources to support TT activities and academic spin-offs, even among more advanced or risk-oriented investors, such as business angels or venture capital firms (Rasmussen and Sørheim, 2012). Technologies and startups stemming from universities are typically characterized by high levels of uncertainty and informational gaps, which make it difficult for external investors to assess business prospects or monitor entrepreneurs once investments are made (Lerner, 2009). Because university-generated inventions are generally at the scientific frontier and often embryonic in nature, the risk they involve in terms of subsequent validation, industrialization, and commercialization is rather high (Jensen and Thursby, 2001; Colyvas et al., 2002; Munari and Toschi, 2011). High information asymmetries, caused by technologies' origin in advanced scientific fields, makes it difficult for external investors to assess the quality of inventions ex ante (Macho-Stadler et al., 2007; Siegel et al., 2007). Such problems reduce the willingness of both debt and equity providers to provide capital to develop university-based technologies and startups.

The literature highlights additional barriers that can limit the provision of funding to technologies generated from universities and public research organizations (Salmenkaita and Salo, 2002). There could be a knowledge gap related to the lack of commercial and management skills and competences on the part of academic researchers and academic entrepreneurs, which are necessary to develop technologies to a point at which they can be commercialized successfully (Franklin et al., 2001). This gap might also affect personnel working within TTOs or incubators, who may not have sufficient and adequate industry experience and education to address the industrial and/or financial fields. In addition, a communication gap can arise at different stages of the TT process between academics and industrial/financial counterparts because actors have different goals, priorities, expertise and language standards (Rogers, 2002).

Such barriers and market failures provide a rationale for government intervention to offer specific financial support with the aim of facilitating the TT process and enhancing its effectiveness, along with its economic and social impacts (Feldman et al., 2002; Link and Scott, 2010; Rasmussen and Rice, 2012).

2.2. Gap-funding instruments: Proof of concept programs and university seed funds

According to the review of Kochenkova et al. (2015), a prevalent area of public policy interventions for TT is direct financial support measures, such as subsidies or commercialization grants, proof-of-concept or translational funds, pre-seed and seed funds, financial support for university incubators or science-parks. This study focuses on this specific set of policy measures – labeling them gap-funding instruments – providing financial support to address the above-mentioned funding gap. We examine two commonly used gap-funding instruments: proof-of-concept programs (POCs) and university seed funds (USFs). POCs aim at evaluating the technical feasibility and commercial potential of early-stage technologies generated by universities and PROs[3]. This type of funding is typically (although not necessarily) provided directly to individual researchers or research teams, often before a start-up or license agreement is in place. USFs are defined as seed and early-stage funds that have an explicit mission to make investments in university and PRO start-ups to support the commercialization of university and public research results.

Despite the increasing use of POC and USF to promote TT, these initiatives have received limited attention in the academic literature (Kochenkova et al., 2015). Table 1 summarizes some of the studies analyzing TT gap-funding instruments, highlighting the measures analyzed, the respective countries, the supporting public institutions and the main results.

--- Include Table 1 around here ---

[3] The measures included in the group "proof-of-concept programs" are labeled in a variety of ways across universities and countries (e.g., proof-of-concept funds, proof-of-principle funds, translational funding, pre-seed funding, verification funding, maturation programs, innovation grants, ignition grants).

As illustrated in Table 1, previous studies mainly provide descriptive accounts of policy intervention regarding the establishment of USFs in different countries, such as Australia (Cumming and Joahn, 2008), United Kingdom (Munari and Toschi, 2015), France (Mustar and Wright, 2010), Belgium (Wright et al., 2006), and Norway (Rasmussen and Rice, 2012), often based on anecdotal evidence. However, detailed studies mapping the presence, implementation and impact of publicly supported USFs across multiple countries is lacking. There is a growing literature on POC programs (Bradley et al., 2013; Gulbranson and Audretsch, 2008; Maia and Claro, 2013); however, scant attention has been devoted to examine the presence and implementation of these programs within and across different countries. As Table 1 suggests, public policies centered on POC have been analyzed in Canada (Rasmussen; 2008; Rasmussen and Sørheim, 2012), Scotland (Rasmussen and Sørheim, 2012), Germany (Uecke et al., 2010), and the United States (Bradley et al., 2013).

Such studies confirm that public support instruments play a key role in the development of the commercialization infrastructure around universities. Moreover, the studies highlight the presence of a high variety of policy solutions, as a consequence of institutional differences across countries and path dependencies imposed by national and regional innovation systems (Geuna and Muscio, 2009; Mustar and Wright, 2010). For such reasons, the convergence of policies towards a one-size-fits-all approach is unlikely to occur. However, current studies present some limitations on the possibility of inferring why public instruments are structured in different ways. First, studies often provide only anecdotal evidence on the structure of such measures and on the role played by national or regional public institutions in their design and implementation. Second, although it is clear that general and standard approaches are not appropriate in this policy area, it is definitively less clear which specific institutional and economic factors influence how such policies are tailored to the contingencies at the national and regional levels. The absence of multi-country comparisons based on quantitative approaches (rather than on descriptive accounts) to link institutional factors to the optimal design of gap-funding instruments thus severely limits the practical insights of such studies

for policy-makers.

An important dimension of such instruments that merits a more detailed investigation is related to their level of centralization or decentralization. The studies summarized in Table 1 suggest that several configurations of gap-funding instruments exist, with solutions based on both a centralized approach (in which the national government or a national innovation agency promote and fund the measure) and a de-centralized approach (in which regional or local public authorities are operating the measure). However, it is not clear under what conditions such instruments adopt a more centralized versus a more decentralized approach. This question has significant implications because it contributes to a growing literature on the varieties of national and regional innovation policies (Klagge and Martin, 2005; Prange, 2008) and the choice of specific instruments in the design of the policy instrument mix (Borrás and Edquist, 2013).

2.3. The centralization/decentralization of public policies for TT

Scholars and policy-makers have paid increasing attention to the role played by the contingent cultural, social and institutional characteristics of the regional context in the development of innovation and knowledge transfer (Edquist, 2011; Klofsten and Jones-Evans, 2000; Laranja et al., 2008; Storper, 2001). Scholars adhering to the regional approach to innovation policies do not believe in a generic and always-effective framework for guiding policy choice, highlighting that there is no ideal model because innovation activities differ greatly between different areas, regions and countries (Tödtling and Trippl, 2005).

To address the important issue of institutional differences, the one-size-fits-all approach has been recognized as deficient with respect to flexible policy measures that account for different potential development paths and needs (Lambooy and Boschma, 2001; Laranja et al., 2008; Rasmussen, 2008). This view is supported by several observations. First, regions may differ with respect to their innovation performance and industrial specialization pattern (Howells, 1999; Breschi, 2000; Paci and Usai, 2000). Second, knowledge spillovers, which represent a key aspect of the

innovation process, are often spatially bounded (Audretsch and Feldman, 1996; Anselin et al., 1997). Third, the growing importance of tacit knowledge for successful innovation emphasizes the regional dimension (Howells, 2002; Tödtling and Trippl, 2005).

As a consequence, different studies have tried to assess the conditions that shape the level of centralization of innovation policies and explain the variation in centralized versus decentralized policies in different countries (Edquist, 2011; Klagge and Martin, 2005; Prange, 2008). This literature has identified a set of country-specific factors that influence the level of regionalized innovation policies. On the one hand, the more general institutional and legal framework of a country is a fundamental factor for determining the degree of regional autonomy (in terms of legal competences, independence and financial resources) towards innovation policies (Baier et al., 2013). Other important factors relate to the concentration of the research, science and innovation system among different regions (Prange, 2008), the diffusion of private funding sources (Klagge and Martin, 2005) and, in the specific case of European countries, the intensity of participation in the European Union (Prange, 2008).

For the specific case of instruments supporting TT activities, an important debate involves the difference of public support measures depending on (a) the institutional context of TT and (b) the design of such policy measures in relation to the territorial level of reference (Wright et al., 2006; Laranja et al., 2008). Some scholars argue that a diversity of funding sources, competition for funding and, in general, a decentralized funding system are more conducive to university-industry collaborations (Bercovitz and Feldman, 2006). According to this view, it is easier for industry to interact in a decentralized system and that a decentralized system is more responsive to the local industrial sector. In comparing systems in which the federal government allocates research funding (such as UK and France) with systems in which states allocate substantial funding (such as US and Germany), Mowery and Rosenberg (1993) assert that the former are not as responsive to industry as the latter. Epure and colleagues (2014) suggest that a supportive regional environment, in terms of resource allocation, can act as an important catalyst that has a strong impact on academic

entrepreneurship and the effectiveness of technology-based spin-offs.

However, a completely decentralized approach in which instruments are designed and implemented only at a regional level may be short-sighted for the effective implementation of TT (Väänänen, 2003). A range of public policies simultaneously undertaken at many levels may cause confusion among different actors and stakeholders (Rasmussen, 2008). Furthermore, this situation may lead to fragmentation of financial resources (with too many programs of limited size and impact) and high overlap between various programs and schemes, which in turn may lead to reduced effectiveness of such measures (Väänänen, 2003). Indeed, to mitigate the risk of fragmentation in policy implementation and resource allocation (Munari and Toschi, 2015), it is important to take into consideration the specific objectives of each support mechanism, clarifying the different natures of such policies and designing them to achieve the most effective result.

In light of the pros and cons of centralized versus decentralized initiatives and the cross-country variations in implementation and performance, a more in-depth investigation of the relevant conditions underlying the implementation of a more centralized (or decentralized) approach is warranted. We intend to contribute in several ways to the debate on public policies for TT by conducting a multi-country comparison. First, we examine the heterogeneity among gap-funding instruments and the differences in their presence among European countries. We map initiatives developed in each country, identifying the type (POCs vs. USFs) and origin (national vs. regional public sources). Moreover, we develop an analytical framework to understand the issue of centralization versus decentralization of such initiatives, discussing the importance of considering the level of development of TT practices and policies at the national level and the nature of the funding gap addressed by the specific instruments.

3. Formulation of hypotheses

3.1. The effect of the degree of development of the national TT system

TT from universities and PROs have become increasingly institutionalized (Geuna and Muscio,

2009), supported by several reforms and initiatives at the governmental, regional and university levels. However, the implementation of "Third Mission" activities at universities (Etzkowitz, 2002) and corresponding entrepreneurial ecosystems (Harrison and Leitch, 2010) have not proceeded uniformly across all universities and countries. In some countries, the uncertain legal assignment of university IPRs or the presence of constraints on the legal status of academic researchers have impeded this process (Lissoni, 2013; Mustar and Wright, 2010). Moreover, several studies have shown that university TTOs, especially in European countries, often are too small and not adequately staffed, thus limiting their ability to encourage a more favorable climate for commercialization (Conti and Gaule, 2011; Siegel et al., 2003). In the specific case of Europe, there are still strong differences between countries in both the overall level of implementation of "Third Mission" good practices and overall TT performance (Arundel et al., 2013; Barjak et al., 2015; Van Looy et al., 2011).

The uneven development of national TT practices and policies have important implications for the design of gap-funding instruments. Evidence regarding the institutionalization path of "Third Mission" activities from various countries, such as the UK (Lockett et al., 2015), Italy (Baldini et al., 2014), Norway (Rasmussen and Gulbrandsen, 2012) and Canada (Rasmussen, 2008), shows that these early stages are typically characterized by a high degree of uncertainty and by a slow process of adaptation, often driven by mimetic isomorphism by the actors involved (Langford et al., 2006). In this phase, the role exerted by the central government is fundamental, not only in defining a clear legislative framework (Weckowska et al., 2015) but also in providing dedicated funding to foster the creation and diffusion of new organizational practices, such as TTOs. In the UK, for instance, a series of important policy initiatives introduced in the 1990s – such as the Higher Education Reach out to Business, the Science Enterprise Challenge, and the Higher Education Innovation Fund – provided for the first time dedicated funding for universities to engage in commercialization activities (Lockett et al. 2015).

The diffusion and strengthening of structures dedicated by universities (and often by regional authorities) to TT and the concurrent increase in the number of people working on commercialization

activities is likely to require a less prominent role for central government intervention. In this phase, it is important to encourage a bottom-up approach in the development of commercialization initiatives by encouraging regional authorities and academic institutions themselves to experiment with new approaches and initiatives. At this stage, measures more tightly connected to current needs at the operational level become particularly important (Rasmussen, 2008; Weckowska et al., 2015). In addition, an increasing level of decentralization at this stage may stimulate the involvement of other local stakeholders, such as industry or private financial actors. Decentralized measures, promoted by regional or local authorities, can likely be more easily and effectively implemented in cases in which adequate TT institutions and infrastructures already exist. Such implementation is unlikely to occur in the early phases of development of university TT activity in a given country. Therefore, we advance the following hypothesis:

H1: Gap-funding instruments are more likely to be centralized in countries with low implementation of technology transfer practices compared to countries with high implementation of technology transfer practices.

3.2. The moderating effect of the type of gap-funding instrument

As highlighted in Section 2.1, various types of gap-funding instruments may be organized differently. POC programs and USFs address different phases of the TT process (earlier phases in the case of POC), target different recipients (projects and teams of researchers in the case of POC, spin-off companies in the case of USF) and provide different forms of financing (grants or subsidies for POC, and equity investments for USFs). POC measures therefore tend to face higher levels of uncertainty and address more severe market failures, given their emphasis on earlier stages of maturation of academic technologies. Moreover, POCs are closer to the science policy area, where funding is typically administered at national level, whereas USFs operate in the area of entrepreneurship and innovation policy, where the use of regional initiatives is more prevalent. Hence, USFs may be

viewed as more relevant at the regional level compared to POC programs as a means to generate spillovers from the science base to the regional economy (Audretsch, Lehmann, and Warning, 2005).

In countries with more developed practices for TT, a broader mix of policy instruments might be expected at both the national and regional levels. The relationship between the probability of centralization of gap-funding policies and the level of development of national TT system may therefore be moderated by the type of instrument used, with respect to POC versus USF programs. Hence, we suggest the following hypothesis:

H2: POC programs are more likely to be centralized than USFs, but this difference is higher in countries with low implementation of technology transfer practices compared to countries with high implementation of technology transfer practices.

4. Data and methods

4.1. Sample and data sources

To provide empirical evidence concerning gap-funding instruments across European countries, a first step was to construct a representative sample of the European context. Identifying relevant policy measures was not straightforward for several reasons. First, policies for TT and commercialization are often combined with more general higher education, economic, and regional policies aiming for broader economic or societal impact. One example is measures aiming to support innovation in general or high-tech new ventures and start-ups in the early phases of their development. Second, such instruments are labeled in highly diverse and sometimes ambiguous ways, such as verification grants, innovation grants, maturation funds, validation programs, proof-of-principle programs, proof-of-concept programs, translational programs and pre-seed programs. Third, in many countries, available information about the measures are provided only in national languages (and not in English); therefore, capturing the different aims of the measures is challenging.

To overcome such problems, we adopted several complementary strategies for policy

identification and data collection: (1) a survey to university TTO managers, (2) dedicated Internet searches, and (3) direct interviews with TT experts in various countries. The cornerstone of our data collection was the FinKT survey to university TTO managers[4], which included a specific set of questions on public policies supporting USFs and POC programs. The questionnaire was designed to provide a multi-country profile of the practices undertaken by TTOs in Europe, with a specific focus on public policies and financial instruments that support TT activities and the obstacles to TT. This first draft of the questionnaire was reviewed by key experts to improve clarity of instructions, completeness of alternatives, and the use of appropriate language and terms. Experts from ProTon, involved in knowledge transfer surveys in Europe and other international experts in TT activities, along with representatives of the European Investment Bank, were consulted several times.

A trial version of the questionnaire was distributed to a small sample of TTO managers between February and March 2013 for a pre-test and data reproduction process. Along with the questionnaire, an additional sheet was included, which provided general instructions and asked for specific information about questionnaire compilation, such as the amount of time required to complete the questionnaire, assessment of the clarity of instructions, and any other comments. This pre-test received 8 responses, which we carefully analyzed. It was observed that i) the average time requested to complete the questionnaire was 15 minutes; ii) instructions were, on average, rated as very clear; and iii) some questions were too complicated. The questionnaire was revised accordingly. The number of questions was reduced to reduce erroneous interpretations and, therefore, to enhance the response rate. Another round of revisions by the key experts was undertaken. After this pilot test, the final version of the questionnaire contained 41 items and two annexes covering the following areas: TTO characteristics; Policies and regulations; Financing mechanisms for TT; Support activities for TT; and Barriers to TT.

The creation of the directory with TTOs' contacts represented a critical step because there is

[4] This survey was conducted within the FinKT (Financing Knowledge Transfer in Europe) research project, sponsored by the EIBURS Programme of the European Investment Bank.

no complete list of all TTOs in Europe. Thus, we proceeded in two steps. We first included the 300 participants at the 2013 Association of European Science and Technology Transfer Professionals (ASTP) Annual Conference. Then, we searched the Internet for a comprehensive list of universities in Europe; for each one we controlled the website to obtain the contact of the related TTO managers. We were able to identify 657 contacts of 559 TTOs across 32 European countries.

The first full printed version of the questionnaire was distributed directly to the 300 participants of the ASTP Annual Conference, held in Vienna in May 2013. We obtained 30 responses. The questionnaire was then uploaded to SurveyMonkey and distributed via email to the remaining contacts on our list in the second half of 2013. Three email-recalls were subsequently performed to non-responding contacts. We then performed a final recall by phone. In total, we received 125 completed questionnaires across 21 countries; a response rate of 19%. Table 2 shows the number of responses and response rates across countries. Of the 32 countries listed in Table 2, 21 are represented in our final sample. Four countries did not respond to the survey (Albania, Croatia, Greece and Romania), likely because they have a limited number of TTOs. Another seven countries (i.e., Hungary, Iceland, Malta) responded to the survey but did not indicate any gap-funding public program to include in our sample. Finally, for the 21 countries included in our analyses, there was some variation in response rates, but the largest countries, such as France, Germany, Spain and United Kingdom, showed relatively homogeneous response rates ranging from 13% to 18%. Hence, our data represent a comprehensive cross-section, which provides reasonably good coverage across European countries.

- Insert Table 2 about here -

Concerning gap-funding instruments, we asked the survey respondents to

1. List university- and PRO-oriented POC programs or seed funding schemes that were available in their universities, regions, or countries to support the commercialization of university

technologies. Each respondent was also asked to state whether the relevant university or PRO had implemented internal POC programs and/or USFs. In addition, respondents could list up to four external USFs and four external POC programs available in the region or in the country with an explicit focus on supporting TT. These questions enabled us to identify the name of the financial instruments that were internally available (i.e., managed by the university itself) or externally available (i.e., managed by other institutions).

2. Specify whether the instruments were supported by public funding sources at the regional or national level. These questions enabled us to identify publicly supported USFs and POC programs.

The respondents mentioned 152 publicly supported USFs and POC programs, distributed across 21 European countries. Because different respondents from the same country sometimes cited the same instrument, we identified 117 distinct gap-funding instruments. Figure 1 shows the number of responses mentioning publicly supported gap-funding instruments, grouped by country. The highest numbers of responses were obtained from Germany (n = 21), Italy (19), France (18), the UK (16), and Spain (12).

- Insert Figure 1 about here -

In a second step, we searched the Internet to verify information each funding program nominated in the FinKT survey and the respective public policies. This step was necessary to double-check the information provided in the survey. At the end of this step, we were able to precisely classify each publicly backed financial instrument according to three dimensions:

1. Nature of the instrument: POC programs and USFs.

2. Source of funding: Instruments funded nationally (i.e., national ministries or public agencies) or regionally (i.e., regional authorities or public agencies).

3. Managing unit: Instruments managed by universities or by external organizations/institutions.

A final complementary step was to contact and interview key experts in the different European countries to verify the accuracy of our information, present an overview of the main public instruments in their country, highlight successful/unsuccessful experiences, and discuss critical factors for the design and implementation of such instruments. Key informants were selected among university TTO managers, VC managers, academic scholars, and IP lawyers and managers. We included people who were directly involved with or experts in the fields of TT, innovation financing, and university–industry collaborations. We arranged on-site and Skype/phone interviews with 41 experts from 20 European countries. All interviews were registered and transcribed through the "Transcribe" tool (available at the link https://transcribe.wreally.com/), which allows audio files to be uploaded and automatically converts them to text, to verify the data collected in the survey. As shown in Table 3, the interviews were selected to obtain diversity in terms of both geographical coverage and field of expertise.

- Insert Table 3 about here -

4.2. Variables

The definitions, construction and the data sources used to operationalize the variables are summarized in Table 4 and described below. The dependent variable was a dummy distinguishing between centralized and decentralized "gap-funding" instruments from our survey data (*Dummy Centralized Policy*). From the same source, we operationalized the moderator variable (*Dummy USF*) to split the sample between POCs and USFs and test Hypothesis 2. The *Implementation of TT practices* variable is based on the Knowledge Transfer Study 2010-2012 by Arundel et al. (2013). This study was commissioned by the European Commission to monitor the status of implementation of the "Recommendation on the management of intellectual property in knowledge transfer activities and Code of Practice for universities and other public research organisations" from 2008. This Recommendation contains 11 policy recommendations for states and regions on how to improve

knowledge transfer from PROs. The recommendations generally reflect the emphasis placed on knowledge transfer in each country, and the degree of implementation of these guidelines can be viewed as a relevant measure of how well a country has developed its TT policies and practices.

Among the control variables, we used the FinKT survey to differentiate between policies in which each university was involved from those in which the university played no direct role (*Dummy University Involved*). At the national level, we assessed the degree of *National Autonomy* with respect to innovation policy according to the methodology applied by Baier et al. (2013), which considers the degree of decision-making autonomy, competences and legislative powers in innovation-related policy making in the fields of research, innovation, technology or education. The distinction in terms of national legislation on IP ownership is based on the recommendation of Geuna and Rossi (2011), which differentiates between nations with the professor privilege model (Italy and Sweden) and nations with the institutional regime. Finally, the last three environmental variables – local economic conditions of the nations in which the policy is implemented (national GDP per capita and national innovation intensity) and availability of VC funding – were based on data from Eurostat.

- Insert Table 4 about here -

5. Analyses and results

5.1 Descriptive statistics

Table 5 reports descriptive statistics for all variables. Of the gap-funding instruments in our sample, 71% percent are centralized, but the variance is high. Centralization is negatively related to *Dummy USF*, *Dummy University Involved*, *National Autonomy* and *Dummy Professor Privilege*, whereas it is positively related to *National Innovation Activities*. POC and USF are equally common, each representing approximately 50% of the gap-funding programs. Furthermore, in approximately 20% of cases, the university plays an active role in the management of the instruments, and this variable appears to be positively correlated with the implementation of TT practices and negatively correlated

with USFs (compared to POC programs). Additional descriptive statistics are shown in Table 5.

- Insert Table 5 about here –

Table 6 shows the breakdown of the sample by country along two main dimensions: the distinction between centralized and decentralized policies and the distinction between POCs and USFs.

Centralized measures are typically funded either by a central ministry (e.g., the Federal Ministry of Economics and Energy in Germany for the EXIST Program, the Ministry for Education and University in Italy for the Proof of Concept Network) or by a national innovation agency (e.g., VINNOVA in Sweden, Tekes in Finland). Decentralized measures are typically funded by a regional innovation agency on behalf of the regional government (e.g., Invest Northern Ireland in the UK for the Northern Ireland Spin Out Funds, the Brabant Development Agency in the Netherlands for the Bright Move Fund). Panel A of Table 6 suggests that the presence of decentralized gap-funding instruments is greater in Western European countries (in particular, Belgium, Germany and The Netherlands) and limited or absent in Southern countries (in particular, Portugal, Spain and Turkey) and Eastern countries (Czech Republic, Estonia, Poland and Slovenia). This finding suggests that public instruments tend to be more often decentralized in countries with a more prolonged experience in TT activities and with a more developed TTO system available at universities and PROs. This relationship will be tested in the next section using multivariate analyses.

The breakdown of publicly supported gap-funding instruments by type shows that POCs and USFs are almost equally distributed, 50.4% and 49.6%, respectively. As shown in Panel B of Table 6, these percentages vary significantly across countries. Respondents from Eastern European countries (Czech Republic, Estonia) and Northern European countries (Norway, Finland) tend to quote more frequently POC programs compared with USFs, whereas USFs are cited more frequently in Western European countries (Austria, France, Germany, the Netherlands). Southern European

countries appear to have a balance between the two types of gap-funding programs (Italy, Portugal and Spain).

- Insert Table 6 about here –

Table 7 presents some examples of gap-funding instruments in Europe: the EXIST Program in Germany, the Fonds National d'Amorcage in France and the VFT measure in Sweden are funded at the national level; the Wales Technology Seed Fund, the NISPO Funds (both in the UK) and the IOF program in Belgium are funded at the regional level.

- Insert Table 7 about here –

5.2 Regression analyses

To test our hypotheses, we conducted a series of probit regressions with *Dummy Centralized Policy* as the dependent variable. To assess potential problems of multi-collinearity, we calculated the variance inflation factors (VIFs) for all our regressions. None of the scores approached the commonly accepted threshold of 10 (our maximum score of the index was 1.71); therefore, we could rule out the existence of multi-collinearity problems (Marquardt, 1980). However, we also performed a robustness check by adopting the approach of residuals (Bajo et al., 2015). Because *National VC Funding* is correlated with *National GDP* measure, we used *National GDP* and the residuals from a regression of *National VC Funding* on *National GDP* (that we label *National VC Funding (residual)*) as control variables in our regressions. Similarly to *National VC Funding*, *National Innovation Activities* is correlated with *National GDP*. We thus applied the same procedure to obtain the variable *National VC Funding (residual)*. We also performed the same regressions by dropping redundant variables (in our case *National GDP*), and the results were observed to hold (Bowerman et al., 1993).

However, because we believe that the three variables capture different aspects of the national environment, we discuss our results based on the residual procedure.

We report the results of our regressions in Table 8. Model 8.1 is the unconstrained controls-only model. Model 8.2 introduces the degree of implementation of TT practices in linear and quadratic terms to test Hypothesis 1. Model 8.3 incorporates the interaction effects for testing Hypothesis 2.

Regarding our first hypothesis, the probability that a gap-funding public policy is centralized varies as a curvilinear function of the implementation of TT practices. Indeed, the coefficient for *Implementation of TT practices* is negative and significant ($ß = -27.83$, $p < 0.10$), whereas the squared coefficient is positive and significant ($ß = 21.01$, $p < 0.10$), indicating that the effect of uncertainty is non-monotonic – greater national implementation of TT practices decreases the likelihood of centralization, but above a certain level the likelihood of centralization increases. This finding partly confirms Hypothesis 1. In countries where practices and policies for TT are weakly developed, the graph suggests that gap-funding instruments are more prevalent at a centralized level. Capacity-building actions for developing the TT infrastructures may be encouraged in this phase by approaches such as staffing, coaching, training, and networking with industry players and financial investors. When TT policies and infrastructure around universities are more mature, gap-funding instruments are increasingly decentralized to foster the development of commercialization initiatives by the institutions themselves and encourage them to experiment with new approaches and initiatives. However, this relationship is not linear; as in the most mature and professionalized TT environments, centralized measures become more common. This finding is illustrated in Figure 2 (see the black line for the full sample), which shows the probability that a gap-funding instrument is centralized (Y-axis) as a function of the national degree of implementation of TT practices (X-axis).

- Insert Table 8 and Figure 2 about here -

Hypothesis 2 posits that the type of gap-funding policy moderates the relationship between the degree of implementation of TT practices and the probability that gap-funding instruments are centralized. In model 8.3, our fully specified model, the interaction term between *Implementation of TT practices* and *Dummy USF* is positive and statistically significant (ß = 47.694, $p < 0.1$), whereas the interaction with the squared term is negative and significant (ß = -33.689, $p < 0.1$), and a log-likelihood test shows that inclusion of the quadratic interaction further improves the model fit. This relationship is highlighted in Figure 2.

Thus, we provide support for our Hypothesis 2 that POCs are more likely to be centralized than USFs (the dashed curve for POC is always higher than the dotted curve for USFs) and that this difference diminish when countries have implemented more TT practices and policies. As previously explained, the projects targeted by USFs are closer to market and thus more likely to generate economic growth if decentralized. On the other hand, POCs are closer to the research phase (pre-seed stage, before company formation), which is typically funded through centralized instruments. However, the difference between POCs and USFs is more pronounced in countries with low levels of implementation of TT practices. This second result suggests that implementation of TT practices at the national level can provide the appropriate knowledge and critical mass that can be beneficial in the environment of USF investing, thus allowing for a higher degree of centralization. In the case of POCs, however, the existence of a strong TT infrastructure can assist individual researchers across a wide spectrum of areas and effectively advance their technology to a point at which it can be licensed to external industrial partners or a start-up can be created, thus allowing for higher levels of decentralization.

Among the control variables in our regression analyses shown in Table 8, *Dummy University Involved*, *Dummy Professor Privilege*, *National VC Funding* and *National Innovation Activities* were significant. The involvement of the university in the management of public policy and the existence of a well-developed VC market increase the likelihood of centralizing gap-funding instruments.

Conversely, under a national legislation regulating patent ownership based on professor privilege and an environment that nurtures technological activity, the probability of decentralization increases.

In conclusion, we find support for both of our hypotheses. In addition, we detected a U-shaped relationship between the implementation of TT practices in a country and the centralization of gap-funding instruments. Hence, gap-funding instruments are more often organized at the national level either in countries in the early stages of implementing TT practices or in later and more professionalized stages. This main effect, however, is moderated by the type of gap-funding public policy that is implemented. The highest probability of centralization occurs among POCs, compared to USFs, but this effect diminishes in countries that implement more TT practices.

6. Conclusions and implications

The use of government instruments providing financial support to TT is relatively unexplored in the academic literature. This study documents the widespread use of gap-funding instruments across European countries, suggesting a rapid diffusion of policy practice in this area. Whereas previous studies have reported few and young government instruments (Storey and Tether 1998; Rasmussen and Sørheim 2012), we found that proof-of-concept funds (POCs) and university seed funds (USFs) were prevalent across all 21 countries covered by our study. However, the most interesting findings relate to the structural differences in how these instruments are implemented in various countries.

In short, we find that gap-funding policy instruments are organized differently depending on the level of implementation of TT practices in a given country and the specific type of instrument considered. More precisely, we found a curvilinear relationship between the level of centralization and the development of national TT policies and practices, with the highest level of decentralization occurring at intermediate levels of development of national TT policies and practices. Moreover, the type of gap-funding instrument (POC or USF) moderates this relationship.

Our findings highlights the interplay between the spatial dimension in terms of centralization or decentralization, a time-variant context dimension in terms of implementation of TT practices, and

the specific aim of the instrument. These complex patterns provides a basis for discussing and analyzing the benefits and drawbacks of different instruments in light of specific contexts and contributes to the debate on the policy instrument mix (Borrás and Edquist, 2013).

Viewing TT polices through the lens of specific instruments using cross-sectional data runs the risk of overlooking the important role of spatial and historical contexts (Flanagan, Uyarra, and Laranja, 2011). Policy instruments are embedded in a broader policy landscape where different political, economic and social considerations shape the selection and design of specific initiatives. Hence, the patterns revealed in our study may not reflect any optimal policy mix that uncritically can form the basis for policy making. Sweden, for example, is a country that has selected a slightly different policy mix and therefore scores relatively low on our measure of the implementation of TT practices, whereas evidence suggests that Sweden performs well in terms of university-industry TT (Jacobsson, Lindholm-Dahlstrand, and Elg, 2013).

This finding relates to the discussion of whether policy instruments converge across countries over time (Mustar and Wright, 2010). Our study reveals observable patterns across countries that lead us to suggest that the development of gap-funding instruments may follow an evolutionary pattern depending on the degree to which TT practices are implemented at the national level. As countries increasingly adopt TT practices, it appears that the initial instruments at the national level are followed by an increasing diversity that includes various decentralized instruments at the regional level and, ultimately, a convergence to fewer instruments mostly at the national level. In line with our empirical findings, this trend implies a curvilinear relationship between centralization of gap-funding instruments and the degree to which TT practices are implemented at the national level. Centralization is more likely to occur in the early stages of development (to initiate and accelerate the process of institutionalization of TT activities) and in the more advanced stages of development (to refine and complement local initiatives with measures promoting critical mass and selectivity).

This evolutionary pattern suggests that the highest level of decentralization is likely to occur at intermediate stages of implementation of TT practices at the national level. Previous studies have

emphasized the importance of encouraging a bottom-up approach, whereby initiatives are supported by and adapted to the local context (Goldfarb and Henrekson 2002; Rasmussen and Borch 2010). This approach would assure that policy initiatives are well connected to the specific needs within the context where TT projects are developed. It is therefore interesting to observe the variation in the share of nationally and regionally managed initiatives across countries. If national TT practices are weakly developed, the establishment of national instruments might be the only viable option to initiate policy instruments that can effectively promote TT. In contrast, countries with somewhat developed institutions, policies and experiences with TT activities may be better able to make use of decentralized instruments to promote TT.

However, in countries with a well-developed implementation of TT practices, government support instruments must justify their existence by generating high additionality, thus generating effects that would not have been realized without public support (Clarysse, Wright, and Mustar, 2009; Gulbrandsen and Rasmussen, 2012). Such centrally promoted schemes should therefore search carefully for high complementarity and selectivity. Moreover, they should have the critical mass required to support the strong growth of a limited number of high-potential technologies and spin-offs. Such growth may lead to a consolidation of the mix of policy instruments into fewer and better coordinated initiatives, in which some funding sources withdraw and successful regional initiatives are adapted at the national level. A closer investigation of such development patterns is limited by our cross-sectional data, and further research would benefit from taking into account the age of policy instruments and preferably follow their development over time.

Although this study provides an overview of the prevalence and structure of gap-funding instruments, the effect of various types of instruments on TT productivity requires further investigation. This task is challenging because of the high variation in context where these initiatives operate and their different stages of development. Moreover, as clearly illustrated by our study, most countries have a mix of centralized and decentralized initiatives that constitutes an ecosystem of funding sources. Hence, comparing single initiatives without considering their complementary and

sometimes competing roles in relation to other initiatives may lead to false conclusions. Using the TT project or spin-off firm receiving support as the unit of analysis would be a viable approach to explore the use and interplay of different gap-funding instruments and other policy initiatives. This approach may also reveal non-financial aspects of government support instruments that could have strong implications regarding the manner in which such mechanisms are organized.

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Figures and Tables

Figure 1 Number of responses indicating gap-funding public instruments in the FinKT survey, by country

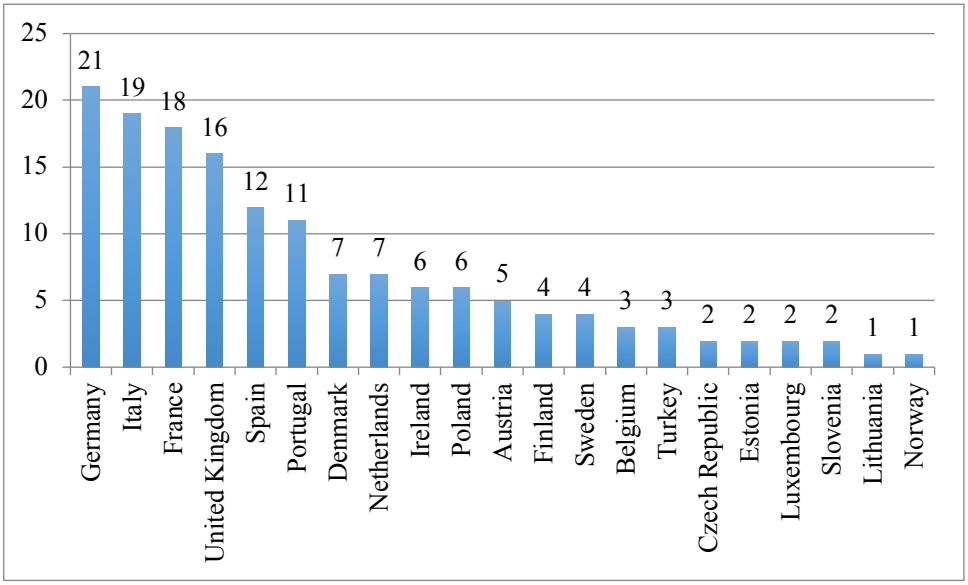

Figure 2 Interaction of the type of gap-funding instruments with the implementation of technology transfer practices with respect to the probability of centralization

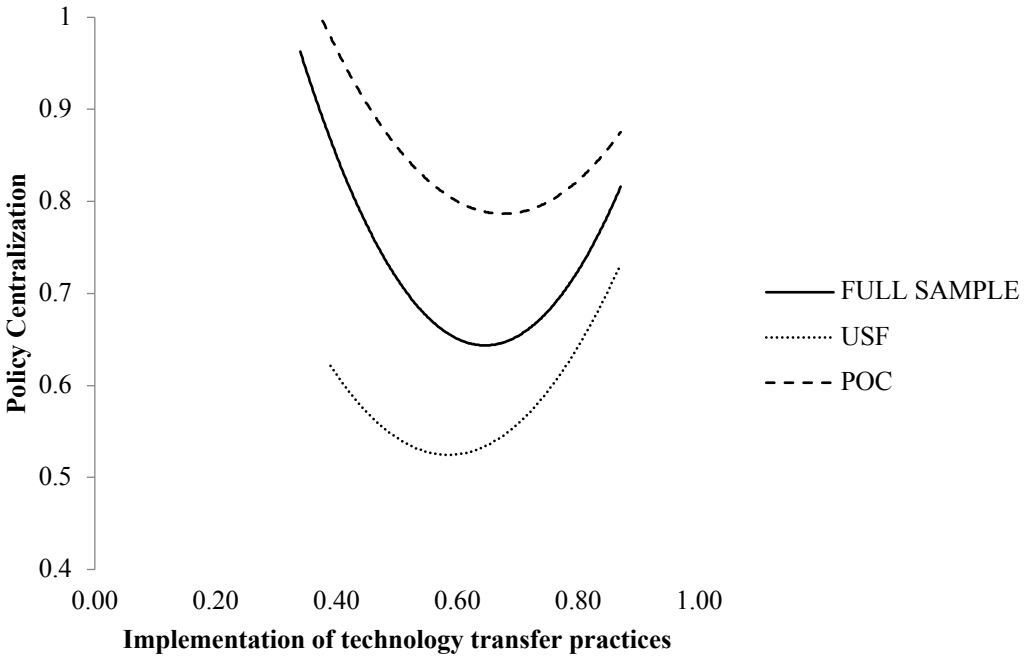

Table 1 Selected studies analyzing gap-funding public policies and instruments

Authors/Year	Gap-funding policies analyzed	Country	Types of instrument*	Funding institution	Main results
Wright et al. (2006)	Various policies in different European countries	Various European countries	USF/POC	National and regional public institutions in various countries	The authors describe and classify various types of policy measures focused on pre-seed and seed stages in Europe up to 2006.
Rasmussen (2008)	A set of POC policies in Canada	Canada	POC	National public institutions, such as the Industrial Research Assistance Program (NRC-IRAP)	The study discusses various policy initiatives to support technology transfer in Canada, highlighting a generally positive effect of such initiatives, as measured by the performance levels of recipient startups.
Cumming and Johan (2008)	Pre-Seed Fund in Australia	Australia	USF	Australian Government	The study analyzes the investment strategy and the performance of companies backed by the Pre-Seed Fund, highlighting mixed performance in terms of finance and governance.
Mustar and Wright (2010)	University-oriented seed funds in France and the UK (i.e., University Challenge Funds, UK)	France and the UK	USF	National public institutions (UK Government; French Government)	The study compares a set of policies in support of technology transfer in the two countries, showing that there was no convergence in the paths due to different rationales and approaches.
Rasmussen and Sørheim (2012)	Various POC, pre-seed and seed capital policies	Canada, Finland, Ireland, Norway, Scotland, Sweden	USF/POC	National and regional public institutions in various countries	The study reports case studies in six countries to explore how specific public programs in support of technology transfer are organized.
Bradley et al. (2013)	Proof-of-concept centers	United States	POC	US Government (Startup America Initiative)	The study identifies the population of the proof-of-concept centers established by US universities and briefly describes the various initiatives.
Uecke et al. (2010)	ForMaT Scheme in Germany	Germany	POC	German Federal Ministry for Education and Research	The authors describe a program called "ForMaT – Research within a Team for the Market", initiated with the goal of fostering knowledge and technology transfer. The proof-of-concept grants obtained through this program focus specifically on the early stages of the technology transfer process to identify and evaluate technologies for application in new products and services.
Munari and Toschi (2015)	University Challenge Funds	UK	USF	UK Government	The study analyzes the performance of startups backed by publicly supported seed funds in the UK, including the University Challenge Funds established to promote the growth of university spin-offs

Table 2 Response rate, by country

Country	Number of contacts	Number of responses	Response rate
Albania	1	0	0%
Austria	21	4	19%
Belgium	20	2	10%
Bulgaria	5	1	20%
Croatia	2	0	0%
Czech Republic	11	2	18%
Denmark	7	2	29%
Estonia	4	1	25%
Finland	28	2	7%
France	75	12	16%
Germany	135	15	11%
Greece	5	0	0%
Hungary	7	3	43%
Iceland	3	1	33%
Ireland	14	3	21%
Italy	42	20	48%
Latvia	6	1	17%
Lithuania	4	1	25%
Luxembourg	2	2	100%
Malta	1	1	100%
Netherlands	10	4	40%
Norway	5	3	60%
Poland	41	4	10%
Portugal	10	8	80%
Romania	3	0	0%
Slovakia	3	1	33%
Slovenia	3	1	33%
Spain	59	9	15%
Sweden	17	5	29%
Switzerland	21	5	24%
Turkey	2	1	50%
United Kingdom	90	12	13%
Total	**657**	**126**	**19%**

Table 3 Key experts interview details

Country	# interviews	Role		
		TTO Manager	Researcher/ Academic	Other*
Austria	1		1	
Belgium	3	1	1	1
Czech Republic	1	1		
Finland	2	2		
France	3	1	1	1
Germany	3	2	1	
Hungary	1	1		
Ireland	1	1		
Italy	7	3		4
Luxembourg	2			2
Netherlands	1	1		
Norway	1	1		
Poland	1	1		
Portugal	1		1	
Slovenia	1	1		
Spain	1			1
Sweden	2	1	1	
Switzerland	4	3	1	
Turkey	1			1
United Kingdom	4	1	2	1
Total	41	21	9	11

* The category "Other" includes IP lawyers, VC managers and policy advisors.

Table 4 Definition of main variables

Variable	Description	Source
Dummy Centralized Instrument	Dummy variable that takes a value of 1 if the gap-funding instrument has a centralized structure and 0 otherwise.	FinKT Survey
Implementation of technology transfer practices	Degree of implementation of TT code of practice by country, expressed as percentage of the European Commission's 15 TT recommendations implemented by PROs as of December 2012.	Arundel et al. (2013)
Dummy USF	Dummy variable that takes a value of 1 if the gap-funding public policy is a USF and 0 otherwise (a POC program).	FinKT Survey
Dummy University Involved	Dummy variable that takes a value of 1 if a university is involved in the gap-funding public policy, and 0 otherwise.	FinKT Survey
National Autonomy	Level of competences and legislative powers in innovation-related policy making by country, measured on a 3-point Likert scale ranging from "full centralization" (1) to "strong decentralization" (3).	Baier et al. (2013)
Dummy Professor Privilege	Dummy variable equal to 1 if the national legislation regulating patent ownership on academic inventions is based on a professor privilege model (Italy and Sweden) and 0 otherwise (institutional regime).	Geuna and Rossi (2011)
National GDP	Gross domestic product (GDP), expressed as euro per inhabitant, at current market prices by country on December 2013.	Eurostat
National VC Funding	Venture capital investments, expressed as percentage of GDP, by country in December 2013.	Eurostat
National Innovation Activities	Employment in technology and knowledge-intensive sectors, expressed as percentage of total employment, by country on December 2013.	Eurostat

Table 5 Descriptive statistics for the overall sample and correlation matrix (N = 117)

	Variable	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9
1	Dummy Centralized Policy	0.709	0.456	0	1	1								
2	Development of National TT System	0.618	0.137	0.34	0.87	0.013	1							
3	Dummy USF	0.496	0.502	0	1	-0.248***	0.080**	1						
4	Dummy University Involved	0.205	0.406	0	1	-0.167**	0.249***	-0.123**	1					
5	National Autonomy	1.761	0.639	1	3	-0.322***	-0.202**	0.131**	-0.108**	1				
6	Dummy Professor Privilege	0.162	0.370	0	1	–0.150**	-0.379***	-0.066**	-0.164**	0.093**	1			
7	National GDP	29435.9	12185.01	8100	83400	–0.027	0.259***	-0.045	0.127**	-0.104**	-0.070**	1		
8	National VC Funding	10.301	12.374	0.06	78.22	0.178**	0.212**	-0.097**	0.121**	-0.338***	-0.257***	0.774**	1	
9	National Innovation Activities	45.318	7.510	22.60	61.40	-0.031	0.430***	-0.059	0.296***	-0.167**	-0.444***	0.649***	0.555***	1

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 6 Distribution of centralized vs. decentralized gap-funding instruments (Panel A) and of POCs vs. USFs (Panel B), by country

		Panel A				Panel B			
Country	**Total**	**Policy Centralized (#)**	**Policy Decentralized (#)**	**Policy Centralized (%)**	**Policy Decentralized (%)**	**POC (#)**	**USF (#)**	**POC (%)**	**USF (%)**
Austria	3	2	1	66.7%	33.3%	0	3	0.0%	100.0%
Belgium	2	0	2	0.0%	100.0%	1	1	50.0%	50.0%
Czech Republic	2	2	0	100.0%	0.0%	2	0	100.0%	0.0%
Denmark	6	6	0	100.0%	0.0%	2	4	33.3%	66.7%
Estonia	2	2	0	100.0%	0.0%	2	0	100.0%	0.0%
Finland	4	4	0	100.0%	0.0%	3	1	75.0%	25.0%
France	17	11	6	64.7%	35.3%	6	11	35.3%	64.7%
Germany	11	4	7	36.4%	63.6%	3	8	27.3%	72.7%
Ireland	6	3	3	50.0%	50.0%	4	2	66.7%	33.3%
Italy	17	9	8	52.9%	47.1%	9	8	52.9%	47.1%
Lithuania	1	1	0	100.0%	0.0%	0	1	0.0%	100.0%
Luxembourg	2	2	0	100.0%	0.0%	2	0	100.0%	0.0%
Netherlands	4	1	3	25.0%	75.0%	1	3	25.0%	75.0%
Norway	1	1	0	100.0%	0.0%	1	0	100.0%	0.0%
Poland	5	5	0	100.0%	0.0%	2	3	40.0%	60.0%
Portugal	5	5	0	100.0%	0.0%	2	3	40.0%	60.0%
Slovenia	2	2	0	100.0%	0.0%	1	1	50.0%	50.0%
Spain	10	8	2	80.0%	20.0%	6	4	60.0%	40.0%
Sweden	2	2	0	100.0%	0.0%	2	0	100.0%	0.0%
Turkey	3	3	0	100.0%	0.0%	2	1	66.7%	33.3%
United Kingdom	12	10	2	83.3%	16.7%	8	4	66.7%	33.3%
Total	117	83	34	70.9%	29.1%	59	58	50.4%	49.6%

Table 7 Examples of gap-funding public policy instruments in various European countries

Name of the publicly supported gap-funding measure	EXIST Program	Fonds National d'Amorcage	VINNOVA Verification for Growth (VFT1)	Wales Technology Seed Fund	Northern Ireland Spin Out (NISPO)	Industrial Research Fund (IOF)
Country/region	Germany	France	Sweden	UK (Wales)	UK (Northern Ireland)	Belgium (Flanders)
Type of instrument (POC/Seed)	Proof-of-concept program	University Seed Funds	Proof-of-concept program	Seed fund	Proof-of-concept program	Proof-of-concept program
Type of configuration	Centralized configuration	Centralized configuration	Centralized configuration	Decentralized configuration	Decentralized configuration	Decentralized configuration
Institution promoting the instrument	Federal Ministry of Economics and Energy	French Government, BPI (Programme d'investissements d'avenir)	VINNOVA	Finance Wales	Invest Northern Ireland	IWT
Objectives of the instrument	EXIST is a support program of the Federal Ministry of Economics and Energy (BMWi) aimed at improving the entrepreneurial environment at universities and research institutions and increasing the number of technology- and knowledge-based business start-ups. It now includes three program lines: EXIST Culture of Entrepreneurship, EXIST Business Start-Up Grant, and EXIST Transfer of Research.	The Fonds National d'Amorcage measure was launched in 2011 to make investments in seed funds managed by professional management teams that perform their own investments in innovative companies in seed stages. Many of them were established in collaboration with universities or public research organizations, as in the case of Inserm Transfer Initiative, EMERTEC (CEA), 3T Capital (Institut Mines Telecom)	VINNOVA supports the VFT program to streamline the process for the commercialization of research results and ideas from researchers, students, and staff from universities and research institutes. It offers the possibility to conduct a more comprehensive commercial and technical verification and validation of a research result with commercial potential. Verification for growth is divided into different steps: VFT-1 and WIN-Verification (VFT-2).	The five-year Wales Technology Seed Fund aims at helping technology start-ups, university spin-offs, and IP-rich companies to commercialize their innovative products and technologies and bring them to market.	The Invest Growth Proof of Concept Fund enables individuals, start-ups, micro-enterprises and small and medium-sized enterprises to establish the commercial potential of a concept resulting from in-house research and ideas. It is funded by Invest Northern Ireland and set up as a pre–commercial grant-awarding fund managed by E-Synergy.	IOF project funding can be applied at crucial stages of the development track of valorization-oriented projects to offer valuable support to research results/technology with clear value-adding potential.

Brief description of the instrument	The EXIST program is part of the German government's "High-Tech Strategy for Germany" and is co-financed by funding of the European Social Fund (ESF). EXIST - Business Start-Up Grants" and "EXIST—Transfer of Research" provide direct financial funding for setting up a new company by means of grants and aim to support the preparation phases of a start-up business (i.e., before the company is officially founded).	The funds were established by the French Government and by BPI with an initial donation of 600 million euro. These seed funds primarily targeted companies in technology sectors defined by the national strategy for research and innovation: health, food and biotechnology, information technology and communication, nanotechnology, environmental technologies.	VFT-1 is intended to validate projects stemming from the early phases of the research. This measure is managed by a VINNOVA-designated holding company or by another regional organization that works with innovation support activities, and it is financed and monitored by VINNOVA itself.	The Fund provides equity investments of between £50,000 and £150,000. It has the potential to help create more than 100 high-caliber jobs over the next five years, and investments from the fund can also be used alongside a range of other Welsh Government support to encourage innovation and business growth.	Grants are distributed in two forms: The Mini Grant (up to £10k) is focused on ascertaining market demand and readiness/receptiveness, assessing the competitive strengths and weaknesses of initial business concepts, and establishing an intellectual property rights strategy. The Standard Grant (up to £40k) is available for later-stage proof-of-concept activities.	The IOF budget is divided between Flemish universities every year based on several criteria of research and TT. Every university then has an intra-university competition to award the IOF funding to projects.

Table 8 Results of probit regression analyses (N = 117)

Model	**8.1**	**8.2**	**8.3**
VARIABLES	**Dummy Centralized Policy**	**Dummy Centralized Policy**	**Dummy Centralized Policy**
Constant	2.672***	11.675**	21.954**
	(0.872)	(4.736)	(9.153)
Independent variables			
Development of National TT System		-27.825*	-55.067*
		(16.888)	(28.949)
Development of National TT System ^2		21.010*	39.942*
		(13.295)	(21.774)
Dummy USF		-0.187***	-1.00**
		(0.088)	(0.001)
Moderating variables			
Development of National TT System * Dummy USF			47.694*
			(26.243)
Development of National TT System ^2 * Dummy USF			-33.689*
			(19.547)
Control variables			
Dummy University involved	0.165*	0.110	0.101*
	(0.077)	(0.066)	(0.068)
National Autonomy	-0.660***	-0.293	-0.364
	(0.249)	(0.370)	(0.420)
Dummy Professor Privilege	-0.338	-0.609**	-0.671**
	(0.216)	(0.252)	(0.293)
National GDP	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)
National VC Funding (residual)	0.055*	0.140*	0.142
	(0.030)	(0.079)	(0.093)
National Innovation Activities (residual)	-0.101*	-0.208**	-0.217**
	(0.057)	(0.098)	(0.109)
Model Diagnostic			
Log Likelihood	-57.592	-49.726	-47.155
Chi2	25.845	41.576	46.719

We display marginal effects computed at the discrete change from 0 to 1 for dummy variables and at the mean for continuous variables.

Standard errors in parentheses: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$