Bridging the University Funding Gap: Determinants and Consequences of University Seed Funds and Proof-of-Concept Programs in Europe

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Preface

Technology transfer is a strategic area for the European Investment Fund (EIF). It can be defined as the process of transforming the results of research and development into marketable products and services. This transformation can take place through a number of means, in particular the collaboration between research organisations and industry, the licensing of Intellectual Property Rights, and the creation of start-up businesses or university spin-out companies.

The EIF has become one of the main European investors providing guidance and cornerstone funding to players in this emerging market segment, notably K.U.Leuven/CD3 (Belgium), IP Group (UK), Chalmers Innovation Seed Fund (Göteborg, Sweden), the UMIP Premier Fund (Manchester, UK) and Karolinska Development (Sweden). In addition, there is growing interest in the commercialisation of IP through vehicles that pool and license patents and that address the proof of concept funding gap. Against this background, research to shed more light on technology transfer and in particular its success factors is of paramount importance to us.

The project 'European IP regimes and their impact on technology transfer/IP finance' was launched in 2011 by the EIF with support from the EIB-University Research Sponsorship Programme (EIBURS). A call for expression of interest was issued and led through a competitive process to the selection of the University of Bologna, Italy.

With the creation of the EIB Institute, EIBURS became an integral part of the Knowledge Programme (one of the three flagship programmes of the Institute); this programme aims to provide support, mainly through grants or sponsorship, to higher education and research activities. EIBURS supports university research centres working on research topics and themes of major interest to the EIB Group. EIB bursaries, of up to EUR 100,000 per year for a period of three years, are awarded through a competitive process to university departments or research centres associated with universities in the EU, Accession or Acceding Countries.

This particular research project, which finished in April this year, aims to broaden the understanding of appropriate funding instruments, in order to bridge the financing gap, thus enabling the support of technology transfer activities from universities to the industry and markets. It provides important empirical evidence and enhances the understanding of factors that affect the creation of university gap funding measures, their design, and effectiveness. This working paper forms part of the output of the project, more information can be found here: http://finkt.unibo.it/.

We thank the researchers for their important work over the three year period. We also thank the additional steering group members (Marc D'hooge, Bastiaan de Laat, Mark Mawhinney, Marc Schublin, Patrick Terroir, Piyush Unalkat and Jacques Van Der Meer) who provided very helpful advice during the entire research project.

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Bridging the University Funding Gap:

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and Proof-of-Concept Programs in Europe

Abstract

The limited availability of private funding sources to support technology transfer activities represents a major barrier to the effective commercialization of university technologies. This working paper analyzes the key determinants of use of financial instruments by universities - such as seed funds and proof-of-concept programs - to address such funding gaps. Using data from a survey of technology transfer office managers in European universities, the authors detail the antecedents of the presence of such instruments at the university level and their perceived effectiveness. The findings in turn have notable policy implications.

Keywords: Funding gap; university seed funds; proof-of-concept programs; technology transfer

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1 Introduction

Growing attention from national governments and regional authorities has focused on the development of technology transfer (TT) activities, to facilitate the flow of ideas from universities into industry. The lack of private funding sources to support such activities in their different forms—the so-called funding gap—constitutes a major barrier to the effective commercialization of university technologies though (Benner and Sandstrom, 2000; Lockett and Wright, 2005; Munari and Toschi, 2011). Traditional funding sources have limited relevance for research spin-offs and university technologies, because they feature significant information asymmetries, uncertain technological and commercial success, and long-term horizons for commercialization (Audretsch et al., 2012).

To address these challenges, various universities and public research organizations (PROs) have invested formally in the creation of internal financial mechanisms to support translational research and fuel the growth of academic spin-offs, often in collaboration with public institutions (Darcy et al., 2009; Lerner, 2009; Wright et al., 2006). In recent years, two complementary financial instruments, aimed at favoring the maturation and commercialization of university technologies (i.e., "gap funding" instruments), have received increasing attention in policy debates and academic literature, namely, proof-of-concept (POC) programs (Bradley et al., 2013; Gulbranson and Audretsch, 2008) and university seed funds (USFs) (Croce et al., 2013; Munari and Toschi, 2011). However, our understanding of the appropriate conditions for activating such funding instruments, their optimal design, and their ultimate effectiveness remains limited. Therefore, the current study seeks to address three key research questions:

1. What are the key factors in technology transfer offices (TTO), the university, and the environment that determine the activation of gap funding instruments by universities?
2. How effective are these instruments, according to university TTO managers?
3. Does effectiveness vary according to the design of the different instruments?

Understanding the factors that affect the creation of university gap funding measures may support university policies, organizational practices, and public policy choices, leading to a more favorable environment for the successful exploitation of results from research activities.

To investigate our research questions, we rely on empirical evidence from a survey of 128 university TTO managers in Europe (for details see chapter 3.1). Of these, 51 universities ran either an internal POC program or an internal seed fund scheme. With data from the survey, we first report a series of descriptive analyses of university-managed gap funding programs in Europe (e.g., average amount of funding per company, funding sources, distribution by countries). Next, using a regression framework, we investigate which factors determine the presence of gap funding instruments at the university level. The resulting multilevel framework includes series of influential factors at the TTO level (size, experience, autonomy), university level (size, age, scientific ranking, legal status, specialization), and environment level (gross domestic product (GDP) per capita, public support to R&D activities, innovation intensity, availability of venture capital funding, university intellectual property rights regime).

Finally, with another regression framework, we assess what factors determine the perceived effectiveness of gap funding instruments, compared with a sample of other gap funding programs, managed externally (not by universities or PROs), that we identified in our survey. We conclude by discussing the policy implications of our findings for the design and implementation of effective gap funding programs in support of technology transfer activities.

2 Literature Review

2.1. Objectives and structure of "gap funding" instruments

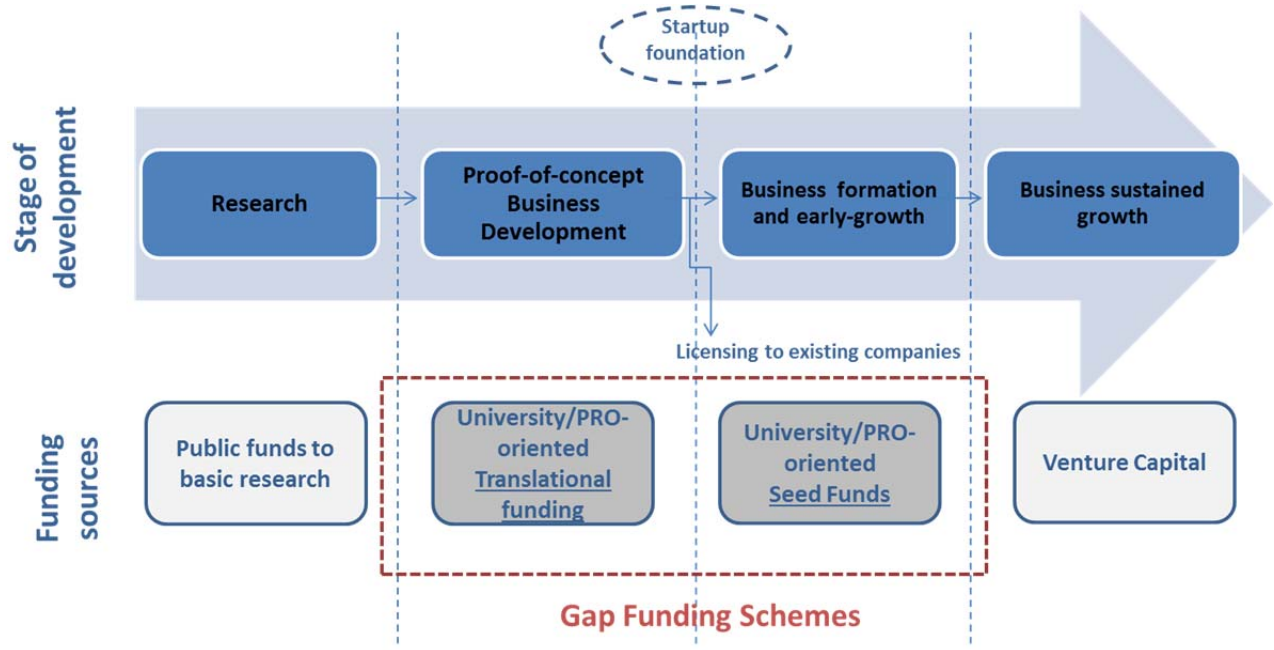
The commercialization of new inventions and technologies is a widespread, added component to the activities of modern universities and PROs. In addition to their primary mission of engaging in research and disseminating knowledge through teaching, there is a growing need for universities to develop tighter linkages between science, technology, and innovation and contribute to local economic and societal development (Etzkowitz, 2002; O'Shea et al., 2005). Yet several questions regarding the effectiveness of these "Third Mission" activities of universities remain (Lerner, 2009; Wright et al., 2006). Both developed and emerging economies have implemented policy initiatives to support knowledge transfer activities from academia to industry (OECD, 2013). The EU research policy framework (i.e., Horizon 2020 Agenda) increasingly encourages the pursuit of such activities, with the goal of gaining significant economic advantages from the high levels of research expenditures allocated to the different programs. Even in the United States, whose institutional environment is enriched by various, complementary components, interest in finding ways to improve the overall TT system remains high. However, several barriers and inefficiencies limit the transformation of new, research-based inventions into successful products or services.

The first "usual suspect" is the "funding gap"—that is, a lack of private funding sources to support TT activities in their different forms, regardless of the level of development of capital markets (Darcy et al., 2009; Lockett and Wright, 2005; Munari and Toschi, 2011). Such a gap is largely due to the "embryonic" nature of university-generated inventions, which tend to operate at the frontier of scientific advancements, thus involving considerable risks associated with their subsequent validation, industrialization, and commercialization. The time lag required to transform such discoveries into viable products and the vast amount of resources needed to pursue the required development constitute an often fatal mix of high uncertainty and negative cash flows that decreases investment incentives and limits opportunities to secure funding. This general pattern is especially pronounced in science-based sectors (e.g., life sciences, biotechnology), in which specific market and regulatory conditions push the bar even higher for both timing and the amount of resources needed. In the specific case of academic spin-offs, even in markets in which dedicated financial operators, such as venture capital (VC) funds, the general unavailability of private investments stems from high transaction costs, significant asymmetric information between science-based ventures and potential external investors, and high risks pertaining to the uncertainty of project outcomes (Munari and Toschi, 2011; Murray, 2007; Murray et al., 1998). In addition, several countries face a more general underdevelopment of the VC infrastructure because they possess fewer natural, available resources. For these reasons, private VC funding, which is typically focused on later-stage forms of financing, may not be available for academic start-ups at an early stage.

In addition, the so-called knowledge gap is another important aspect raised consistently by different researchers as a complementary filter against a strong flow of new discoveries in the market. When researchers and academics are involved, technical skills tend to be abundant, but managerial and commercial skills often are scant, if present at all. The goals and priorities of these various actors also differ, with corresponding differences in expertise, culture, and language between academics and potential external investors, which might lead to a communication gap, especially during the phases of screening, due diligence, and negotiation. This gap limits the ability of academic teams to access external funding. Such limits likely hinder collaborations between university researchers and investors, thus requiring intervention from third parties (i.e., TTO managers, intermediary agencies) to bridge the communication gap by providing dedicated facilities and consulting assistance.

Overall, the lack of dedicated funding and support to help university/PRO inventions mature to a stage at which they are market and investor ready represents a major obstacle to effective knowledge transfer. Different support mechanisms seek to address these gaps, both as general policies and as specific, local initiatives, including university accelerators and incubators, start-up competitions, and university-managed seed funds (Munari et al., 2014b; Rasmussen and Soreheim, 2012). With this study, we focus on two types of instruments that are diffusing rapidly across universities all over the world: university-oriented proof-of-concept programs and university-oriented seed funds. These gap funding instruments differ significantly in their targets and are labeled in various ways, depending on the involved universities, investors, and countries. Thus, we group them into two major categories to facilitate their identification (see Figure 1):

Figure 1: Representation of POC and USF programs



Source: Authors

First, POC programs represent a recent, innovative mechanism, increasingly embraced by public policies (e.g., Startup America Initiative, EU Horizon 2020 Framework, ERC Proof-of-Concept grants). These programs encompass several funding schemes that combine money, expertise, and

training to help new inventions and discoveries emerge and to demonstrate their technical and commercial feasibility. Despite diverse labels across different universities and nations (e.g., POC funds, proof-of-principle funds, translational funding, pre-seed funding, verification funding, maturation programs, innovation grants, ignition grants), they all share common objectives and characteristics: to evaluate the technical feasibility and commercial potential of early-stage university/PRO ideas and technologies and to demonstrate their value to potential industrial partners and investors. Such programs provide capital and assistance to individual researchers or research teams across a wide spectrum of areas, such as intellectual property rights (IPR) protection, POC building and technical verification, business plan development, market studies, entrepreneurial team formation, and networking with external partners. The ultimate goal is to advance the technology to a point at which it can be licensed to external industrial partners or a start-up can be created, to attract the interest of investors in later stages of development. Funds typically are administered in the form of grants, though different variants are available (e.g., repayment schemes, loans).

Second, USFs are early-stage VC funds that have the deliberate and explicit mission of investing in university and PRO start-ups to support TT and the commercialization of university and public research endeavors. This general definition contains some features that define the nature of the USFs and differentiate them from other types of VC seed funds and from POC programs. Compared with other types of VC funds, USFs explicitly focus on investment in university and PRO start-ups, because they are activated and managed directly by the university/PRO, partly funded by universities/PROs as limited partners, or activated forms of formal partnerships or collaborations with universities/PROs. In contrast with POC programs, which fund individual researchers or projects in the pre-seed phase of development (i.e., before the company's legal foundation), USFs typically invest downstream in newly created start-ups. Their objective is to enhance the development of university/PRO start-ups to a point at which they are ready for investments by professional business angels or venture capitalists (see Figure 1). They typically operate by providing equity capital to investee start-ups, though other forms (e.g., convertible loans) are also possible. Table 1 compares the two types of gap funding instruments by highlighting the differences in their objectives, focus of investment, investment typology, and investment stage.

Table 1: Comparison of POC and USF programs

	University-Related Proof-of-Concept Programs	University-Related Seed Funds
Objective	Evaluate and support the technical feasibility and commercial potential of early stage technologies generated by universities and PROs	Provide capital to university and PRO start-ups to assist the early formation of new company creation and early growth
Focus of investment	Primarily projects by individual researchers or research teams	Primarily university and PRO start-ups
Investments typology	Typically grants, but other forms are possible (i.e., loan, repayment schemes)	Typically equity based, but other forms are possible (i.e., convertible loan)
Investment stage	Pre-seed stage (typically before company formation)	Seed and early stage (business formation and early growth)

Source: Authors

Despite their relative importance, very limited research addresses these emerging financial instruments for TT, and most available studies rely on single cases or anecdotal evidence (Bradley et al., 2013; Croce et al., 2013; Gulbranson and Audretsch, 200; Maia and Claro, 2013; Munari et al., 2014a; Rasmussen et al., 2011). Multi-country comparisons are virtually absent, making it difficult to assess the diffusion of such instruments among universities in various national settings or the influence exerted by institutional and contextual factors. In addition, we suffer from a very limited understanding of the factors that determine the instruments' effectiveness in promoting TT. We seek to address both issues.

2.2. Diffusion of gap funding instruments in universities: A multi-level analytical framework

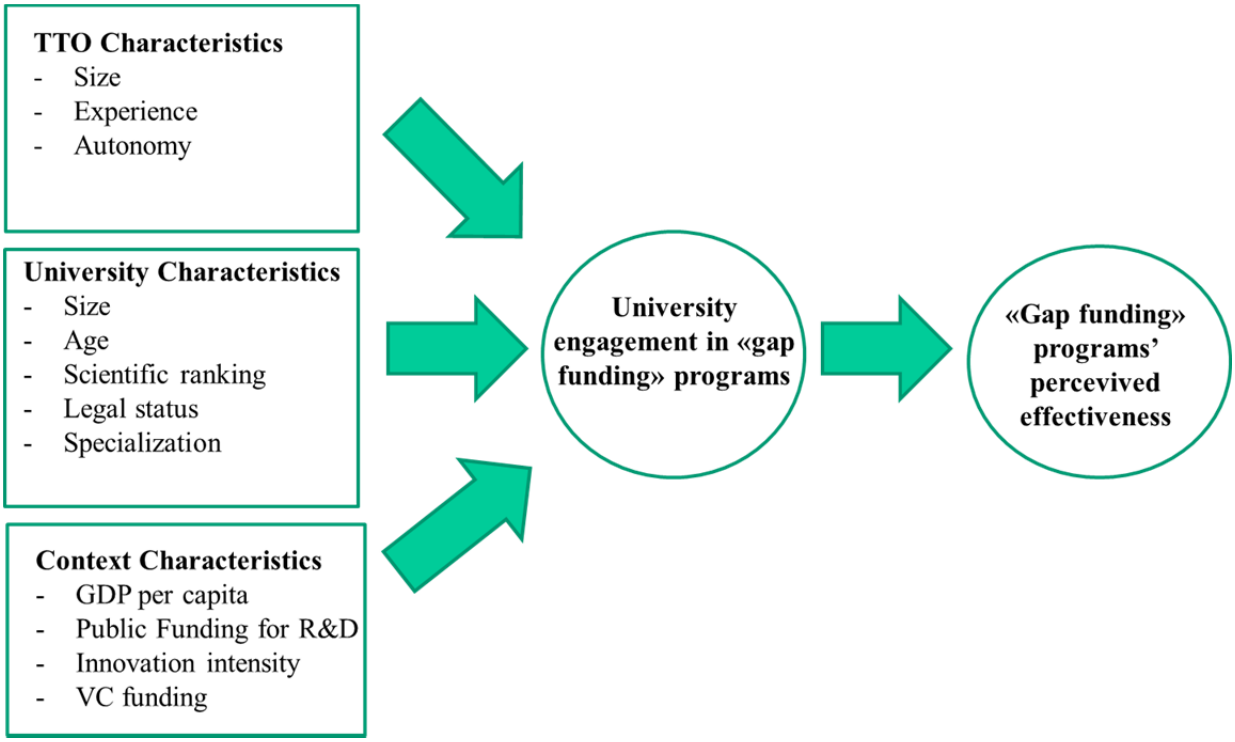
As highlighted in the previous section, the availability of adequate funding instruments that can support the early maturation of university-generated technology represents an important precondition to engage in Third Mission activities. However, they do not necessarily need to be activated and managed by a single university; different organizational configurations might support their implementation. Thus, as our first important question, we empirically investigate the determinants of universities' engagement in gap funding activities. We analyze a set of probable antecedents that might influence a university's decision to establish internal POC programs or USFs. Existing literature is of limited help in this respect. Regarding the diffusion of POC programs among universities, Bradley et al. (2013) provide a descriptive analysis of 32 university-related proof-of-concept centers (PoCCs) in the United States and indicate that they are associated with universities with more established TTOs. However, these authors find no significant differences in the level of R&D research conducted at universities with internal PoCCs and those without them. This exploratory account of the characteristics of PoCCs in the United States offers, as the authors themselves acknowledge, a starting point for considering more detailed questions about the role and impact of POCs. Regarding USFs, Croce et al. (2013) use data from Thomson One to identify 25 USFs, 15 registered in Europe (mostly UK) and 10 in the United States. Their analyses suggest an older genesis of the USF phenomenon in the United States compared with Europe, as well as distinct investment policies. In particular, USFs in the United States tend to invest in more companies, using more rounds of investment and channeling more financial resources toward portfolio companies, compared with European USFs. Their investment strategies also tend to focus on technology sectors rather than life sciences. However, their study does not include an analysis of the influence of university- and context-level characteristics on the presence and impact of USFs.

A broader, clearer picture of the antecedents of gap funding activities by universities therefore would be helpful to extend the general existing literature on universities' engagement in Third Mission activities. This stream of the literature has grown exponentially, with several studies that examine the factors available to explain the adoption of university-level policies and practices in support of technology transfer, such as the creation of dedicated TTOs (Debackere and Veugelers, 2005; Siegel et al., 2003), the adoption of IPR policies and regulations (Baldini et al., 2006; Lissoni et al., 2012), internal incentive systems that support technology commercialization (Baldini, 2010; Friedman and Silberman, 2003; Markman et al., 2005), and the creation of university-managed incubators or science parks (Phan et al., 2005). These studies clearly suggest

that universities' engagement in TT activities is a multilevel phenomenon; they also highlight the importance of considering different factors, at various levels of analysis, simultaneously (Fini et al., 2011; Perkmann et al., 2013).

We build on this insight to develop a multilevel framework to analyze universities' involvement in gap funding activities through POCs and USFs, such that we combine factors at the TTO, university, and environment levels. Figure 2 summarizes the framework and the main variables that we consider.

Figure 2: Multilevel framework to assess universities' engagement in gap funding programs



Source: Authors

The *characteristics of the university TTO* represent the first analytical dimension of our framework. Most university institutions have established formal TTOs, as a way to facilitate technology and innovation diffusion through the creation of spin-off companies or licensing (Debackere and Veugelers, 2005). The spectrum of TT activities performed by universities, and their ultimate performance, therefore depend significantly on the organizational arrangements of their bridging units, as well as the resources and capabilities they possess (O'Shea et al., 2005; Schoen et al., 2014). Existing research shows convincingly that the number of people engaged at the TTO and their relative experience are important determinants of a successful transfer, because it requires time and effort to break through existing cultural barriers that separate the TTO, university scientists, and industry and encourage a more favorable climate for commercialization (Siegel et al., 2003). The age of the TTO also captures learning and experience effects in commercialization activities (Friedman and Silberman, 2003). Another important dimension refers to the degree of integration of the TTO with the university (Derrick, 2015). Various governance models are available, ranging from a classical integrated structure, in which the TTO exclusively serves one university and is fully integrated with its administration, to an autonomous structure,

such that the TTO has significant autonomy from the university's administration and even might act as a separate company (Schoen et al., 2014). According to Etzkowitz (2003), the autonomous model offers advantages over the integrated model if the goal is to create new roles with existing missions. In addition, the autonomous model seemingly could enhance the activation of POC or USF initiatives by universities, by providing the financial and administrative autonomy required to run such types of programs.

If we turn to the *university-level characteristics* that likely influence the decision to activate POCs or USFs, a first logical candidate is university size, as approximated by the number of total staff. Larger universities likely can exploit larger financial endowments to fund their internal gap funding programs; they also benefit from greater visibility and prestige, such that they can attract external sponsors to fuel such initiatives (Bonaccorsi et al., 2014). Similarly, the age of the university might provide benefits in terms of visibility and learning advantages for engaging in Third Mission activities. Another important variable relates to the quality of research at the university level, which likely constitutes an antecedent of involvement in gap funding programs. Although the relationship between the quality of university research and likelihood of engagement in TT activities remains uncertain (e.g., Perkmann et al., 2013), we posit that it enhances the flow of potential inventions that could benefit from POC programs and USFs. In particular, higher quality research should facilitate the creation of a wider, stronger applicant pool and strengthen the selection process, ultimately enhancing the decision to activate internal financial programs in support of TT. In this respect, extensive literature shows that the research quality of an affiliate university increases the likelihood that the researchers participate in commercialization (Di Gregorio and Shane, 2003; Owen-Smith and Powell, 2001), and it enhances academic entrepreneurship activities (Munari and Toschi, 2011; O'Shea et al., 2005).

Another potential antecedent is the level of specialization of the university institution in technical and medical fields. University landscapes are characterized by heterogeneous profiles, in both the number and scope of scientific disciplines covered (Daraio et al., 2011). A classical distinction separates generalist universities, which cover a broad spectrum of disciplines (humanities, social sciences, science, technology, medical), from specialized universities, which focus on specific scientific areas. Within this latter group, technical universities (e.g., polytechnics, universities of applied sciences) and medical schools should have a greater likelihood of generating ideas and inventions with more potential for commercial exploitation. Therefore, they may have stronger incentives and needs to activate internal POC programs and USFs to foster the commercial exploitation of their discoveries. In addition, universities differ in their public versus private status (Daraio et al., 2011). Private universities may be more likely than public universities to respond to the environment that surrounds the TT, such that they may have greater incentives to support the creation of internal gap funding measures.

Finally, the existence of university-related gap funding activities may depend on a series of *environmental characteristics,* related to the regional and national context in which universities operate. The influence exerted by such forces could be matters not only of the supply of additional public or private funding for commercialization activities but also of industry-level demand for science-based technologies and innovations. Regarding the supply of funding, the amount of private third-party funding available in the region, whether as VC funding or industry funding, offers an important complement to universities' internal efforts in gap funding activities, because it

creates, for the beneficiary projects and startups, prime conditions to attract subsequent investment rounds and exit opportunities (Bonaccorsi et al., 2014; Lockett and Wright, 2005). In terms of demand for universities technologies, the regional levels of economic development and innovation intensity represent proxies for firms' willingness to sponsor the development of technologies generated by local universities (Azagra-Caro et al., 2006; Friedman and Silberman, 2003).

2.3. Effectiveness of gap funding instruments

The ex post evaluation of economic and social results obtained through POC programs and USFs should represent a key priority for university TTO managers, related to the design and implementation of these types of programs, as well as for public institutions that fund them. Thus, we also empirically investigate the effectiveness of gap funding instruments, which represents a major challenge for two sets of reasons. First, there are general problems (Cumming, 2007; Munari and Toschi, 2015) associated with assessing the performance of seed funds and early-stage new ventures (in particular, the limited availability of data due to confidentiality issues). Second, the recent and still limited diffusion of gap funding instruments makes it difficult to access a large pool of comparable observations. Therefore, to the best of our knowledge, a very limited number of empirical studies have systematically addressed this topic (Bradley et al., 2013; Croce et al., 2013; Munari et al., 2014a and 2014b).

Different approaches can serve to assess the impact of such funding instruments, as suggested by general literature on the effectiveness of public policies that support TT (see Kochenkova et al., 2014). These approaches can be grouped into three families: (1) a perceived assessment based on questionnaires submitted to recipient companies/projects (e.g., Giuri et al., 2013; Luukonnen et al., 2013); (2) a perceived assessment based on direct interviews with key stakeholders interested in the results of such initiatives, such as TTO managers, VC managers, entrepreneurs, or policy makers (e.g., Wright et al., 2006); or (3) quantitative analyses of the performance of recipient companies and projects, possibly by comparing their effectiveness with that registered by a matched-paired group of other companies and projects (e.g., Cumming, 2007; Croce et al., 2013; Munari and Toschi, 2011).

The only existing study to assess the performance of POC programs that adopts a quantitative approach is that by Bradley et al. (2013), in a U.S. context. These authors consider the potential economic impact of 39 university PoCCs established in the United States by calculating the number of start-ups generated by the respective universities before and after the founding of these centers. Their results show that the number of new university start-ups increased in the years after the founding of the PoCC, though this interpretation is not straightforward for several reasons. First, their analyses are explanatory, and the authors acknowledge freely that they do not account for possible endogeneity issues or other influential covariates. Second, a simple count of spin-offs is an imperfect, narrow proxy for the real impact of such instruments. Third, in the case of USFs, they offer only limited empirical evidence. Croce et al. (2014) and Munari et al. (2014a) present initial, unique evidence related to this topic, adopting the third approach of quantitative analyses. As we noted previously, Croce et al. (2014) exploit data from the Thomson One database to describe the determinants of U.S. and European USFs' performance, in terms of exit rates by portfolio companies (through initial public offering or acquisition). The results suggest that USFs'

exit performance relates to differences between European and U.S. VC market characteristics and USF features (age and diversification). Moreover, better universities (in terms of teaching and research) are more likely to have successful USFs. Munari et al. (2014a) instead focus on the European context and provide an overview of European USFs by comparing the performance (exit rates, staging, and syndication levels) of 733 USF-backed start-ups against the performance of 764 comparable start-ups backed by other VC funds (i.e., non-treated companies). The USF-backed companies perform better in staging and syndication but worse in terms of exit rates, probably due the embryonic and early-stage nature of the companies generated by these universities. Among the group of USF-backed companies, those financed by USFs that are internally managed by and linked to universities with high scientific rankings attract more follow-up funding and investors. However, neither study accounts for the potential influence of more specific characteristics of the universities and their internal TTOs.

To complement this initial stream of the literature, in our empirical analyses, we provide an overall assessment of the performance of gap funding instruments activated by European universities, including both POCs and USFs, using the second approach. That is, we assess the perceived effectiveness of such programs in promoting TT activities, according to a survey of TTO managers from a sample of European universities.

3 DATA AND METHODS

3.1. Sample

We address our research questions using a two-step method to gather data. First, during 2013 and through the research project FinKT (Financing Knowledge Transfer in Europe), we conducted an online survey of 663 TTO managers of European universities, based on an ad hoc questionnaire that included a specific section dedicated to gap funding programs (FinKT survey). The questionnaire was designed to provide a multicountry profile of the financial instruments that support TT activities and obstacles to TT. After a pilot test conducted with a restricted group of TTO managers, the final version of the questionnaire contained 41 items, as well as two appendices that were to be completed only if the university/PRO had an internal POC program. The questionnaire was distributed to participants of the Association of European Science & Technology Transfer Professionals (ASTP) Annual Conference held in Vienna in May 2013. An online version of the questionnaire (through the SurveyMonkey platform) then was distributed to the remaining universities associated with ASTP or PROTON (European Knowledge Transfer Association). Finally, an e-mail directory of TTO contacts was compiled through a web search of university TTOs for several European countries, and we mailed the questionnaire to these contacts too. Three different reminders sought to solicit greater participation. We received responses from 135 universities in 28 European countries, though the final sample includes 128 responses, after we dropped some observations due to limited data availability. Of these respondents, 55 (42% of the full sample) declared the presence of either an internal POC and/or an internal USF. Specifically, 51 respondents indicated the presence of an internal POC, and 30 noted the presence of an internal USF, of which 26 declared the joint presence of both a POC and a USF, and 4 respondents indicated the presence of only a USF. The information on these programs was collected in the appendices to the questionnaire. The questionnaire also gathered information

about TTO characteristics, such as age, number of personnel, and governance. We double-checked these responses in a second phase against information available on the web.

Also in the second phase, we collected complementary data from secondary sources, using the Eumida (European University Data Collection) database to find university-level information.[1] We relied on Eurostat to gather environment-related information (i.e., GDP per capita, innovation intensity, public funding, and VC funding) at regional and national levels. We referred to the NUTS2 geographic level of analysis to collect information on the regions in which the universities were located.

3.2. Variables and econometric models

Table 2 describes the main variables we used in our analyses and the data sources we used to construct them. With regard to our first research objective (i.e., assessing the determinants of universities' engagement in gap funding activities), we adopted three dependent dummy variables that captured the likelihood that a university would activate internal gap funding programs. First, *Internal Gap Funding Program* takes a value of 1 if the university declared the presence of either a POC or USF program at the time of the FinKT survey, and 0 otherwise. Second, *Internal POC Program* equaled 1 if the university declared the presence of only a POC program, and third, *Internal USF program* equaled 1 in the case an internal USF only. For the regression analyses that use these binary variables to assess the probability of a university activating gap funding measures, we used a Probit specification. Then in a second set of regression analyses, we referred to survey data from university TTO managers to assess the respondents' perceptions of the effectiveness of their internal POC programs and USFs. One item asked the respondents to rate, on five-point Likert scales, their perceptions of the effectiveness of such instruments as tools to enhance TT. Such responses were gathered only from those universities that previously indicated the presence of an internal gap funding program.[2] In the perceived effectiveness regression models, we used ordered Probit regressions to account for the categorical and ordinal nature of the dependent variable, for which 1 is the lowest value and 5 corresponds to the highest value.

For all specifications of our models, we included three sets of dependent variables (see Table 2): (1) TTO characteristics, including age, size, and level of integration within the university; (2) university variables, involving size, age, research quality, field specialization, and public vs. private nature; (3) environmental variables, such as national legislation regulating academic inventions (professor privilege versus institutional regime), local economic conditions of the regions in which the university is located (regional GDP per capita, regional public funding, regional innovation

1 Eumida is a research project funded by the European Commission and undertaken during 2009–2011 to build a complete census of European universities. The pilot data collection emphasized active research universities in particular.

2 Unfortunately, only 58 of 81 universities that declared the presence of gap funding programs answered the perceived effectiveness question. Therefore, our regression analyses are limited to this smaller sample. The FinKT questionnaire also asked respondents to nominate external gap funding programs (i.e., POCs or seed funds activated or managed not by the universities but by other actors, such as national or regional public authorities) whose formal mission was to support TT. We also asked the respondents to rate the perceived effectiveness of these external programs (also on five-point Likert scales) to have a comparison standard.

intensity), and availability of VC funding at the national level. In our regressions to assess the perceived effectiveness of the internal instruments, we also controlled for the distinction between internal USF and internal POC programs and between publicly versus privately backed programs. Table 2 describes each variable in detail and the sources we used.

Table 2: Variable definitions

Variable	Description	Source
Internal Gap Funding Program	Dummy variable that takes a value of 1 if the university has activated a gap funding program as of May 2013, and 0 otherwise.	FinKT Survey
Internal USF	Dummy variable that takes a value of 1 if the university has activated a USF program as of May 2013, and 0 otherwise.	FinKT Survey
Internal POC	Dummy variable that takes a value of 1 if the university has activated a POC program as of May 2013, and 0 otherwise.	FinKT Survey
Perceived Effectiveness	Perceived effectiveness of the gap funding measures in promoting technology transfer, measured on a 1–5 Likert scale.	FinKT Survey
TTO Age	Age of the TTO, expressed in years, on May 2013.	FinKT Survey
Internal TTO	Dummy variable that takes a value of 1 if the TTO is an internal department of the university, and 0 otherwise.	FinKT Survey
TTO Size	Size of the TTO, expressed as the number of personnel working at the TTO in 2012.	FinKT Survey
University Size	Size of the university, expressed as the number of personnel working at the university in 2008.	Eumida and Web Search
University Research Quality	Dummy variable equal to 1 if the university is in the top 200 Times Higher Education Ranking of research universities, and 0 otherwise.	THE Ranking
Technical/Medical University	Dummy variable that takes a value of 1 if the university is a technical or medical university, and 0 if the university is generalist.	Web Search
Public University	Dummy variable that takes a value of 1 if the university is public, and 0 otherwise.	Eumida and Web Search
University Age	Age of the university, expressed in years, on May 2013.	Eumida and Web Search
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)
Regional GDP	Gross domestic product (GDP), expressed as Euro (EUR) per inhabitant, at current market prices by NUTS 2 regions on December 2013.	Eurostat
Regional Public Funding	Total intramural R&D expenditure, expressed as Euro (EUR) per inhabitant, by NUTS 2 regions on December 2013.	Eurostat
Regional Innovation Activities	Employment in technology and knowledge-intensive sectors, expressed in thousands, by NUTS 2 regions on December 2013.	Eurostat
National VC Funding	Venture capital investments, expressed as percentage of GDP, by country in December 2013.	Eurostat

Source: Authors

4 ANALYSES AND RESULTS

4.1. Descriptive statistics: the diffusion of university-related POCs and USFs

In this section, we present a series of descriptive statistics to clarify the diffusion of university-related POC programs and USFs in our sample and the characteristics of the institutions that activated them. We also provide an initial characterization of these instruments, according to a series of dimensions that are relevant for design and management, such as the type of funding provided and the sources of their funds. Table 3 contains summary statistics, as well as a breakdown in terms of the geographic distribution of universities across four major country groups: Western European, Eastern European, Northern European, and Southern European countries.[3] As we find in Table 3, European universities feature many internal gap funding programs: 43% of the institutions in our sample reported the presence of an internal funding program (either POC or USF) to support the commercialization of university technologies. About 40% of universities reported the presence of an internal POC program, whereas only 23% indicated an internal USF. A few universities implemented both instruments. The majority of universities with an internal USF (26 of 30) also managed an internal POC program.

It is also worth highlighting that the universities with both internal USF and POC programs all were located in Belgium, Finland, Germany, Sweden, or the United Kingdom. This evidence suggests a second important finding, namely, the uneven distribution of university-related gap funding programs across European countries. The results in Table 3 suggest the important presence of such instruments in Northern European and Western European universities (respectively, in 73% and 52% of universities in our sample) but a very limited presence in Southern European and Eastern European countries (respectively, 5.7% and 25% of universities). Therefore, the funding gap instrument culture appears much better developed in Northern European countries, where universities' involvement in TT practices has a longer history and major public policies have been implemented over time to strengthen the TTO infrastructures at the university level.

Moreover, some characteristics of POC programs and USFs, according to information provided by the respondents (which were subsequently cross-checked on the Internet), suggest some interesting insights as well. In terms of the sources of initial capital for the funding schemes (as identified by a specific item in the survey), the university was the most frequent investor in internal funds, followed by public sources, such as local, national, and international public institutions. In particular, 39% of internally managed POC programs and 30% of internally managed USFs in our survey received funding from national public institutions, while regional authorities were active in about 27% and 22% of the cases for POC programs and USFs respectively. Also institutional investors, such as VC firms and banks, are cited as supporting organizations (VCs account for 20% and 10% and banks for 7% and 4% of USF and POC respectively). Finally, private organizations were less frequently involved as funding sources, though we found investments in 20% of them (14% for POC programs and 6% for USFs). Therefore, funding gap investing is an

3 The groups of countries reflected the location of the respondents' university: Eastern Europe includes Bulgaria, Czech Republic, Estonia, Poland, Russia, and Slovenia; Western Europe includes Austria, Belgium, France, Germany, Hungary, Luxembourg, Netherlands, Slovakia, and Switzerland; Northern Europe includes Denmark, Finland, Iceland, Ireland, Lithuania, Norway, Sweden, and United Kingdom; and Southern Europe includes Italy, Malta, Portugal, Spain, and Turkey.

arena in which public intervention has a fundamental role, coherent with theoretical arguments about the persistence of market failures in this area. Most existing European schemes resulted from specific public policies, aimed at strengthening TT from universities and PROs. Regarding the typical amount of money provided per project or company through such instruments, our data indicate that for POC and USF, the average level of funding provided per project equals about EUR 55,000 and EUR 543,000 respectively (with median values equal to about EUR 49,500 for POCs and EUR 180,000 for USFs). The maximum amount provided for projects is instead equal (on average) to about EUR 98,000 for POCs and EUR 1.1m for USFs (with median values equal to about EUR 75,000 for POCs and EUR 500,000 for USFs).

A further look at the characteristics of the TTOs and universities in our sample reinforces the existence of significant differences among European countries. On average, a university TTO in our sample employed around 11 people, had been in existence for around 11 years, and was usually structured as an internal unit of the university. However, significant differences emerge across countries, such that TTOs from Eastern European countries were smaller (around 9 people) and younger (around 5 years) than TTOs from Northern and Western European countries (respectively, 14 and 13 people, and 13 and 13 years). The TTOs from Southern European countries fell in the middle. In terms of university characteristics, we note that on average, the universities included in our sample had a total staff of around 2,900 people, though Eastern European universities were significantly smaller (around 1,900). Universities in our sample that also appeared in the Times Higher Education Ranking tended to concentrate in Northern and Western European countries but were substantially absent in Southern and Eastern European countries. Approximately one-quarter of our sample universities were technical/medical schools, particularly concentrated in Eastern and Western European countries (in the latter case, largely due to Germany's influence).

Table 3: Summary Statistics (total sample and breakdown by group of countries)

This table summarizes the data for the universities of the full sample and the different European areas represented (Eastern, Northern, Southern, and Western Europe). The number of observations, the mean, the standard deviation, the minimum, and the maximum values are provided. For definitions of the variables, see Table 2.

		Internal Gap Funding Program (dummy)	Internal USF (dummy)	Internal POC (dummy)	Performance (1–5 Likert scale)	TTO Age (years)	Internal TTO (dummy)	TTO Size (staff units)	University Size (staff units)	University Quality (dummy)	Specialist University (dummy)	Public University (dummy)	University Age (years)	Professor Privilege (dummy)	Regional GDP (€ per inhab)	Regional Public Funding (€ per inhab)	Regional Innovation Intensity (staff units)	National VC Funding (% of GDP)
	Obs	128	128	128	48	128	128	128	128	128	128	128	128	128	128	128	128	128
Full Sample	*Mean*	0.430	0.234	0.398	3.500	11.078	0.852	10.891	2879.234	0.242	0.250	0.938	182.875	0.211	29.989	85.916	1217.461	0.026
	SD	0.497	0.425	0.492	0.851	7.922	0.357	13.267	2170.599	0.430	0.435	0.243	203.545	0.410	14.932	92.552	865.075	0.020
	Min	0	0	0	1	0	0	1	180	0	0	0	1	0	6.125	0.215	173	0.003
	Max	1	1	1	5	46	1	85	11606	1	1	1	924	1	81.212	452.417	5255	0.092
	Obs	12	12	12	1	12	12	12	12	12	12	12	12	12	12	12	12	12
Eastern European Universities	*Mean*	0.250	0.083	0.167	3.000	4.750	0.917	8.750	1916.667	0.000	0.417	0.917	66.750	0.000	13.634	67.881	815.500	0.017
	SD	0.452	0.289	0.389	0.000	4.093	0.289	6.690	1064.866	0.000	0.515	0.289	32.974	0.000	8.523	36.061	325.632	0.013
	Min	0	0	0	3	1	0	2	400	0	0	0	1	0	6.694	3.133	440	0.004
	Max	1	1	1	3	14	1	22	3905	0	1	1	124	0	29.989	124.172	1311	0.038

Table 3 continued:

	Obs	37	37	37	24	37	37	37	37	37	37	37	37	37	37	37	37	37
Northern European Universities	*Mean*	0.730	0.486	0.703	3.458	12.811	0.811	13.919	3198.568	0.432	0.162	0.946	161.541	0.162	37.119	77.612	915.243	0.041
	SD	0.450	0.507	0.463	0.658	8.900	0.397	15.091	2032.949	0.502	0.374	0.229	127.885	0.374	18.230	96.141	461.384	0.019
	Min	0	0	0	2	0	0	1	253	0	0	0	5	0	8.906	0.215	173	0.021
	Max	1	1	1	5	46	1	60	9272	1	1	1	535	1	81.212	452.417	2346	0.08
	Obs	35	35	35	3	35	35	35	35	35	35	35	35	35	35	35	35	35
Southern European Universities	*Mean*	0.057	0.057	0.029	2.333	9.429	0.914	6.257	2912.914	0.029	0.029	0.943	224.657	0.600	24.918	43.003	1739.171	0.007
	SD	0.236	0.236	0.169	1.528	5.237	0.284	5.982	2087.874	0.169	0.169	0.236	283.968	0.497	6.311	39.347	1071.014	0.007
	Min	0	0	0	1	2	0	1	180	0	0	0	14	0	13.058	5.962	177	0.003
	Max	1	1	1	4	24	1	26	9222	1	1	1	924	1	33.536	215.559	4298	0.026
	Obs	44	44	44	20	44	44	44	44	44	44	44	44	44	44	44	44	44
Western European Universities	*Mean*	0.523	0.205	0.500	3.750	12.659	0.818	12.614	2846.432	0.318	0.455	0.932	199.250	0.000	32.486	131.951	1166.227	0.030
	SD	0.505	0.408	0.506	0.851	8.635	0.390	16.116	2523.892	0.471	0.504	0.255	196.938	0.000	13.585	110.391	866.033	0.017
	Min	0	0	0	2	1	0	1	290	0	0	0	3	0	6.125	0.946	241	0.009
	Max	1	1	1	5	41	1	85	11606	1	1	1	647	0	78.247	414.325	5255	0.092

Source: Authors

Regarding effectiveness, as perceived by TTO managers, our descriptive analyses show that the average assessment of such instruments is largely positive (average value of 3.5 on five-point scale), confirming the importance of such tools for undertaking the commercialization of university technology. Across countries, our analyses indicated the relatively lower assessments of such measures by TTO managers from Southern and Eastern European universities (average perceived effectiveness = 2.333 and 3.000, respectively) compared with Western and Northern European universities (average perceived effectiveness = 3.750 and 3.458, respectively).

In Table 4 (Panel A), we compare the mean values of TTO-, university-, and environment-level characteristics across universities with internal gap funding programs and those without such instruments. We also differentiate the former group into two subsamples: universities with only internal POC programs and universities with only internal USFs. We ran statistical tests to uncover any differences in the proportion or means for each variable, to assess the significance levels of the reported differences. The TTOs of universities with an internal gap funding program tended to be significantly older than their counterparts (on average, 12.30 years vs. 10.15 years) and significantly larger in terms of internal personnel (on average, 15.30 employees vs. 7.56 employees). No statistically significant differences emerged regarding the TTO governance arrangements (integrated vs. autonomous) though. Therefore, a TTO of viable size and experience appears necessary to manage internal gap funding programs. In particular, USFs require more funding and higher commitment levels. Regarding university characteristics, we also note that universities with and without internal gap funding programs do not differ in size. Nor do we find any major differences (at least at conventional statistical levels) in the degree of specialization (technical/medical vs. generalist universities) or public versus private status.

A more sizeable difference instead emerges for university research quality. Universities in the former group have a significantly higher likelihood to be included in the top 200 world universities of the Times Higher Education Rankings, compared with the latter group. Our data further suggest that when national legislation regulating patent ownership of academic inventions encourages inventor ownership (so-called professor privilege, as in Italy and Sweden), rather than institution ownership, universities tend to be less likely to activate gap funding programs (in only about 9% of cases, compared with 30% under the institutional regime). Furthermore, contexts with high GDP pro capita and VC funding seem to create optimal conditions for gap funding programs. We found similar results in separate analyses of the two split samples of universities with POC or USF programs. Thus, our descriptive analyses indicate that a supportive institutional environment is a critical contextual factor for activating gap funding instruments.

With Table 4 (Panel B), we focus on the perceived effectiveness of internal gap funding programs, according to TTO managers, between internal USFs and POC programs and between publicly and privately supported internal programs. We did not find any statistically significant differences in perceived effectiveness across these pairs of groups.

Table 4: A comparison of universities with and without gap funding programs

Panel A summarizes the data by universities, distinguishing in Columns (1-2) universities with and without a gap funding program (both USF and POC), Columns (3-4) with and without a USF program, and Columns (5-6) with and without a POC program. The mean values and comparison of proportions tests (for dichotomous variables) or mean tests (for continuous variables) are indicated. Panel B summarizes the perceived effectiveness, according to TTO mangers, of the different internal gap funding programs, as indicated. It also contains the mean values and comparisons of mean tests.

Panel A	(1)	(2)	(2) - (1)		(3)	(4)	(4) – (3)		(5)	(6)	(6) – (5)	
	Gap Funding Program	No Gap Funding Program	Difference Tests		POC Program	No POC Program	Difference Tests		USF Program	No USF Program	Difference Tests	
Number of observations	55	73			51	77			30	98		
	Mean	*Mean*	*Proportion*	*Mean*	*Mean*	*Mean*	*Proportion*	*Mean*	*Mean*	*Mean*	*Proportion*	*Mean*
TTO age	12.309	10.151		-2.158*	12.353	10.234		-2.119*	13.000	10.490		-2.510*
Internal TTO	0.818	0.876	0.059		0.824	0.870	0.047		0.800	0.867	0.067	
TTO size	15.309	7.562		-7.747***	15.510	7.831		-7.679***	17.533	8.857		-8.676***
University size	3069.982	2735.521		-334.4613	3160.118	2693.195		-466.923	3368.933	2729.327		-639.607*
University research quality	0.418	0.110	-0.309***		0.451	0.104	-0.347***		0.533	0.153	-0.380***	
Technical/medical university	0.291	0.219	-0.071		0.255	0.247	-0.008		0.333	0.224	-0.109	
Public university	0.927	0.945	0.018		0.922	0.948	0.026		0.933	0.939	0.005	
University age	181.909	183.603		1.694	177.608	186.364		8.756	175.700	185.071		9.371
Professor privilege	0.091	0.301	0.210**		0.098	0.286	0.188**		0.133	0.235	0.101	

Table 4 continued:

Regional GDP	35.448	25.875	-9.579***	36.284	25.819	-10.465***	37.378	27.727	-9.652***
Regional public funding	92.481	80.969	-11.512	88.478	84.219	-4.259	122.652	74.670	-47.982**
Regional innovation intensity	1138.345	1277.068	138.723	1133.196	1273.273	140.077	1280.867	1198.051	-82.816
National VC funding	0.036	0.018	-0.018***	0.037	0.018	-0.019***	0.034	0.023	-0.011**

Panel B	(1)	(2)	(2-) – (1)	(3)	(4)	(4) – (3)
	Internal USF	Internal POC	Difference Tests	Public Internal Gap Funding Program	Private Internal Gap Funding Program	Difference Tests
Number of observations	19	29		26	22	
	Mean	*Mean*	*Mean*	*Mean*	*Mean*	*Mean*
Perceived effectiveness	3.421	3.552	0.131	3.423	3.591	0.168

Source: Authors

4.2. Regression analyses

We also consider the results of a multivariate analyses (Table 5), by detailing the Probit regression models we used to analyze the likelihood that universities had (or not) an internal gap funding program (POC or USF) (Model 1), only a POC program (Model 2), and only a USF (Model 3). Then we present the results of the regression model in which we analyzed differences in perceived effectiveness (1–5 Likert scale) of internal gap funding programs (Model 4), as reported by TTO managers.

In Table 5, Models 1–4 consistently indicate that the TTO size variable exerted a positive effect on the likelihood to activate a gap funding program (i.e., coefficients are statistically significant at the 10% level). This effect was more pronounced for POC programs (.007) compared with USFs (.005), in alignment with our previous findings about the importance of maintaining a TTO with viable size—which appears critical not only to succeed in the complex TT process but also to be able to manage the related programs. In terms of university characteristics, we observe that only quality in terms of research activity offered a significant antecedent of the university's engagement in gap funding instruments. That is, research quality emerged as a key factor for USFs (coefficient = .284, significant at 5%) and for POC programs (coefficient = .279, significant at 5%). The variable that captures university size was not statistically significant though, suggesting that rather than the number of academic staff working at the university, it is the quality of the research performed that matters for the decision to activate gap funding programs.

We confirm the idea that institutional and economic contexts that support innovation are critical for university engagement in gap funding instruments, especially in terms of the availability of additional VC funding sources. Universities operating in countries with professor privilege ownership models for patents by academic inventors are less likely to activate a POC program than are universities that function under an institutional regime (coefficient = -.231, significant at 10% for POC programs; not significant for USFs). A clear assignment of patent rights to universities (rather than academic inventors) thus constitutes an important precondition for engaging in gap funding measures, in that it provides the institution with greater certainty about ownership rights.

Furthermore, the availability of VC funding at the national level emerges as a critical contextual factor, supporting the activation of gap funding initiatives (coefficient = 9.229, statistically significant at 1%), especially for POC programs (coefficient = 9.591, 1% level, versus 4.024, 10% level for USFs). Therefore, complementary funding sources that support subsequent phases of technology maturation and commercialization facilitate universities' decision to engage in gap funding activities.

The analysis of Model 4 related to the perceived effectiveness of internal gap funding instruments reinforces these findings. Perceived effectiveness is higher when the internal gap funding program has been activated by a top performing university in terms of research activity (coefficient = .762, statistically significant at 10%) and when IPR legislation is regulated by an institutional regime (coefficient for professor privilege = -1.156, statistically significant at 10%). Furthermore, programs operating in countries with a strong presence of VC funding seem to attract more positive evaluations (coefficient = 29.81, statistically significant at 5%).

Table 5: Regression analyses

This table presents Probit analyses of the likelihood of activating an (1) internal gap funding program, (2) an internal POC, and (3) an internal USF, according to the 128 observations in our sample. Model (4) presents the results of the perceived effectiveness of gap funding programs, according to an ordered Probit specification.

Each model uses three groups of control variables (TTO-, university-, and environment-level characteristics). Marginal effects are provided for Models 1–3. Coefficients are provided for Model 4. Standard errors are in parentheses. *** $p < .01$. ** $p < .05$. * $p < .1$.

	(1)	(2)	(3)	(4)
VARIABLES	Internal Gap Funding Program	Internal POC	Internal USF	Perceived Effectiveness
Internal USF				-0.0291
				(0.380)
Public Gap Funding Program				-0.277
				(0.398)
TTO-level Characteristics				
TTO Age	-0.00263	-0.00267	-0.00128	0.0378
	(0.00642)	(0.00634)	(0.00511)	(0.0345)
Internal TTO	-0.00134	0.0290	-0.0250	0.519
	(0.144)	(0.143)	(0.111)	(0.491)
TTO Size	0.00821*	0.00756*	0.00517*	-0.00880
	(0.00483)	(0.00481)	(0.00330)	(0.0143)
University-level Characteristics				
University Size	-0.001	-0.001	-0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
University Research Quality	0.219	0.279**	0.284**	0.762*
	(0.140)	(0.139)	(0.126)	(0.459)
Technical/Medical University	0.0975	-0.0102	0.0292	0.00787
	(0.124)	(0.123)	(0.0925)	(0.459)
Public University	-0.0149	-0.0468	0.0626	-0.231

Table 5 continued:

	(0.214)	(0.216)	(0.143)	(1.768)
University Age	0.000217	0.001	-0.001	0.000768
	(0.000306)	(0.000312)	(0.000233)	(0.00117)
Environment-level Characteristics				
Professor Privilege	-0.271**	-0.231*	0.0101	-1.156*
	(0.127)	(0.126)	(0.118)	(0.738)
Regional GDP	0.00587	0.00694	-0.00166	0.0117
	(0.00551)	(0.00574)	(0.00337)	(0.0181)
Regional Public Funding	-0.000937	-0.00120*	0.000559	0.000385
	(0.000676)	(0.000695)	(0.000422)	(0.00249)
Regional Innovation Intensity	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.000215)
National VC Funding	9.229***	9.591***	4.024*	29.81**
	(3.512)	(3.487)	(2.396)	(15.14)
Constant	-1.381*	-1.502*	-1.923**	
	-0.758	(-0.783)	(0.880)	
cut1				-0.266
				(2.253)
cut2				0.649
				(2.225)
cut3				2.506
				(2.269)
cut4				4.177*
				(2.291)
Observations	128	128	128	48
Model	Probit	Probit	Probit	Ordered Probit

Source: Authors

5 DISCUSSION AND POLICY IMPLICATIONS

The findings of our analyses help shed light on the critical factors that should guide universities in deciding whether to activate internal gap funding instruments, such as POC programs or USF, to help academic technologies transition into markets. They also suggest important implications for university managers and policy makers interested in enhancing the effectiveness of TT activities through dedicated funding instruments. In particular, the responses to our survey highlight a significant diffusion of gap funding instruments among universities; 55 out of 128 universities declared that they had activated some gap funding programs. A closer look at the data reveals though that their diffusion at the university level is uneven across Europe. Their presence is relatively well-established in Nordic and Western European countries, where universities have more experience engaging in Third Mission activities. Conversely, they are relatively scarce (if not absent) in Southern and Eastern European countries.

Our survey-based analyses of the funding sources that back university-managed gap funding programs also suggest that, in addition to the direct internal financial support by the university, important investors for POC programs include public sources, such as local, national, and international public institutions. In contrast, TTO managers cited private organizations (e.g., corporations, banks, VC funds) less frequently as funding sources. In funding gap investing, public intervention thus has a fundamental role, coherent with theoretical arguments about the severe market failures in this area, as we discussed previously. Most schemes in Europe have been initiated and developed by specific public policies, geared to strengthen TT from universities and PROs. Collaborations among university managers, TTO managers, and external stakeholders from national and regional public institutions thus are critical to program implementation.

Moreover, our study highlights some profound practical implications for understanding the conditions in which universities *should* implement these types of internal instruments. With regard to TTO- and university-level factors, two characteristics emerge as particularly critical: the size of the TTO and the research quality of the university. Our results suggest that a TTO must reach viable size before it can manage these types of gap funding programs (i.e., in our sample, average number of TTO employees was around 15 for universities that had an internal gap funding measure). The size of the TTO relates not only to the amount of financial resources required to invest in such programs but also to the ability to support them with a team of professionals who possess adequate skills and experience to select, support, and monitor the funded companies/projects. Thus, it is important to establish TTOs that combine expertise in evaluating research projects from an industrial perspective with an ability to communicate across groups that are separated in their jargon, priorities, and expectations. The TTOs of universities with gap funding programs tend to be larger and more experienced than their counterparts without such programs. Therefore, some minimum levels of TTO staff, resources, and expertise are required to effectively manage internal USFs and POCs.

The availability of high-quality science at the university level is another important precondition, as clearly emerges from our analyses. The quality of the university research base guarantees a steady stream of high-potential companies and the possibility of developing a diversified portfolio of high-quality companies in which to invest. Our results thus suggest that small-scale universities, rather than directly activating and autonomously running their own funding programs, should

consider collaborating with other universities or partnering with governments and regional authorities to promote bridging structures, which might create critical mass through bundled projects and technologies across institutions, lower operation costs, and engage more professional personnel. Collaborative or regional/national solutions should benefit single institutions that are less prominent in their size or quality. The ultimate goal is to increase the pool of candidates eligible for the program and thus enhance the likelihood of finding high-quality projects. Although the potential benefits of such solutions are clear, especially in terms of overcoming the limited ability of small or mid-sized universities, their potential costs also require consideration, especially as they relate to coordination costs, the presence of additional administrative layers, and conflict generation.

Another interesting insight is related to the role of the institutional and legal framework concerning ownership of university IPRs. Our findings suggest that establishing gap funding instruments is problematic in presence of an ambiguous or conflictual set of rules and laws regulating IPR issues and academics' involvement in technology transfer, both at the national and the university level. In our analyses, the existence of a national "Professor's privilege" system on university IPRs is negatively associated with the existence of gap funding instruments at the university level. A possible explanation for this related to the assignment of patent ownership rights to the inventor (rather than to the institution) in this type of systems, an issue which can create uncertainties and ambiguities in the assignment of IPRs from the point of view of external investors. This uncertainty in fact is likely to raise transaction costs in the activation of licensing agreements and collaborations with industrial partners, or in the access to external finance. This evidence therefore suggests the importance of having a clear set of rules and laws on university IPRs and researchers' involvement in technology transfer as a critical condition to establish gap funding initiatives.

Finally, our study contains some limitations that suggest new avenues for research. Our descriptive, survey-based evidence about the gap funding programs suggests that they tend to be heterogeneous in several dimensions, such as fund size, amount of funding per project, type of support activities in addition to funding, and funding sources. Incomplete data prevented us from analyzing in detail how the structural characteristics of gap funding programs determine their ultimate effectiveness. This point represents an important challenge for research, which should seek deeper insights into the critical success factors for the design and implementation of such financial instruments. Moreover, we used a simple and rather crude measure of perceived effectiveness.

Additional studies should investigate effectiveness, in a more robust way, using objective, quantitative measures of success at the recipient company or project level (Munari et al., 2014a). Ideally, research would analyze the share of POC- versus USF-backed projects that attract additional funding from other sources (and the amounts), such as external public bodies (i.e., regional or national governments or innovation agencies, such as EU funding), business angels, VC investors, or industry partners. Because the ultimate outcomes of such programs depend on the ability of the supported technologies to reach commercialization and generate returns, in the form of commercial and R&D contracts with industry, additional outcome indicators for POC- or USF-backed projects could include revenues from licensing deals or financial income from selling shares of university spin-offs. In terms of methodological approaches, researchers should compare the commercialization success of projects funded by university-related gap funding instruments

with that of a control group of projects backed by other funding instruments or unfunded projects, to disentangle any additional effect of such programs. Our study represents a first empirical effort, at the European level, to assess the influences on and perceived effectiveness of an innovative set of gap funding instruments, which represent important levers for commercializing science-based inventions.

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