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Public policy measures in support of knowledge transfer activities: a review of academic literature

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Abstract Despite the wealth of academic studies that analyze different policy measures and initiatives implemented by national or regional governments to support knowledge transfer from academia to industry, scant systematization efforts seek to integrate these disparate lines of research. The systematic review of academic studies on public policy measures in support of technology transfer presented by this article suggests a literature classification based on two dimensions: the type of policy measure analyzed, and the focus of the study (i.e., policy design vs. impact assessment). On the basis of this comprehensive review, we summarize the lessons learned thus far, identify research gaps that continue to limit insights into public policy measures for technology transfer, and highlight directions for further research.

Keywords Public policy measures · Government support of technology transfer · Commercialization of university research · Knowledge transfer from academia to industry

JEL Classification M13 · O31 · O38

1 Introduction

National governments and regional authorities actively seek to encourage technology transfer activities from universities to industry, often in line with the increased emphasis on the "third mission" of universities, which is to sustain and develop national and regional

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economic systems (Etzkowitz et al. 2000; Gulbrandsen and Slipersæter 2007; Rasmussen and Borch 2006). In addition to making new products, processes, and services available to wider markets, the commercialization of university research outcomes can contribute to addressing social, cultural, and environmental challenges, and it is an important mechanism for industry development (Rasmussen and Rice 2012). Furthermore, as government funding for research has continued to decrease generally (Calderini et al. 2003; Geuna 1998), commercialization of research knowledge represents a promising source of income for universities (Baldini et al. 2010; Etzkowitz et al. 2000). Thus, universities also regard technology transfer activities as important means to defend their positions, create new mechanisms for funding research activities (e.g., royalties on licensed technologies, revenues earned from shares in academic spinoffs, research contracts, consulting services with companies), and strengthen their general reputations to attract the brightest students and researchers (Baldini et al. 2010).

This revised role of universities has been embedded as an integral element of many government-sponsored innovation policies (Mansfield and Lee 1996). Even as the number of government support programs and invested resources increase though, understanding of how to integrate disparate practices into conceptual models and thereby ensure the optimal impact of the related programs and greater returns on investment remains scarce. Different nations and their distinct universities exhibit considerably varying approaches to encourage university knowledge transfer (Geuna and Muscio 2009). Yet most analyses of policy measures and initiatives rely mainly on benchmarking and experimenting, rather than validated conceptual frameworks (Feldman et al. 2002).

Another stream of research, mainly in economics and management of innovation fields, seeks to analyze the design and impact of public policy measures aimed at increasing technology transfer activities and university–industry links, especially those that rely on formal mechanisms such as patenting, licensing, or spin-off creation. However, most of these studies focus on the experience of a single country or investigate a limited number of public support measures (e.g., Goldfarb and Henrekson 2003; Mustar and Wright 2010; Rasmussen 2008; Rasmussen and Rice 2012). The field lacks a systematic account of the lessons learned, which makes it difficult to produce clear, evidence-based recommendations for policy. We need a comprehensive study to systematize scientific literature on public policy measures that support technology transfer activities.

To address this gap, this study provides a classification of existing studies of the role of government in facilitating the commercialization of academic research and university–industry collaborations. Compared with previous literature reviews of technology transfer policies (e.g., Bozeman 2000; Geuna and Muscio 2009), this article presents several novel elements. First, we adopt a precise focus on policy measures to foster technology transfer activities at the national or regional level, whereas previous studies consider, in more general terms, relevant contextual factors or university-level policies. Second, this study introduces several new analytical dimensions for classifying existing literature, which should facilitate the identification of unaddressed issues and promising avenues for research. Specifically, we classify existing literature according to the policy measures implemented, for which we identify three macro-level policy interventions analyzed previously: legislative/institutional reforms, direct financial support measures, and competence-building measures. In addition, we delineate the focus of prior studies, whether on the design of public policy measures in support of technology transfer or on the ultimate impact of those measures. Whereas the former category adopts a descriptive approach to the aims and features of various policies implemented in different countries, the latter set of studies seeks to assess the effectiveness of programs using different approaches and performance indicators. Both these dimensions of analysis facilitate our interpretations of extant findings; they also highlight research gaps and promising research avenues. Third, our proposed classification helps clarify salient issues and provides insightful implications for policy makers who seek to design evidence-based policies.

The remainder of this article is organized as follows: Sect. 2 describes the methodology we used, and then in Sect. 3, we discuss the rationales for government intervention in the commercialization of university knowledge, obtained from the set of articles we identified. Section 4 presents the conceptual framework we use to review existing academic research; Sect. 5 provides a detailed account of the main public policy measures used to support knowledge transfers that existing literature has described. Finally, we discuss the identified research gaps and critical issues, along with policy implications and recommendations, in Sect. 6.

2 Review methodology

To develop a comprehensive overview of academic research on public measures to support university knowledge transfer, we started with electronic reference retrieval services such as Scopus, Google Scholar, and Proquest and ran keyword queries to identify scholarly articles published in refereed journals, working papers, and book chapters related to public policy measures designed to enhance technology transfer and university–industry collaborations. We used the following keywords (and their combinations) to retrieve relevant articles: "technology/knowledge transfer," "university–industry collaboration," "public support mechanisms/measures," "government support," "venture capital," "university seed funds," "academic start-ups/spin-offs," "university incubator," and "science park." The initial sample obtained from this search included more than 80 studies. We scanned each article and selected only those that explicitly referred to public support mechanisms aimed at enhancing university knowledge transfer activities (not innovation in general or entrepreneurship at large). Moreover, we included only studies with in-depth investigations of specific, single policy measures or a wide set of measures oriented toward technology transfer but excluded studies that mentioned policy measures only marginally, because they had a different ultimate aim. The resulting sample included 46 studies that we detailed in a database to specify the (1) author name(s), article title, and year published; (2) research question(s); (3) public policy measure(s) considered; (4) focus (i.e., description of the design or characteristics of the measure or its impact); and (5) main findings and conclusions. The following review is based on these collected data.

3 Rationales for public intervention in support of technology transfer activities

The increased numbers of technology transfer across countries in recent decades have, in large part, been supported by public policy measures dedicated to fostering technology transfer activities by universities or public research organizations (Feldman et al. 2002). To pursue such objectives, governments have intervened by enforcing legislative acts and other regulations related to intellectual property (IP) ownership and exploitation of research results (Baldini 2006; Della Malva et al. 2008; Geuna and Rossi 2011; Lissoni et al. 2013), as well as establishing publicly funded structures and programs to support universities in their commercialization activities (Rasmussen 2008; Rasmussen and Rice 2012; Wright et al. 2006). According to economic literature, the main justifications for public interventions that support universities' "third mission" activities cite the persistence of barriers, in the form of market inefficiencies (e.g., Salmenkaita and Salo 2002).

Arguably the most significant hurdle among market inefficiencies is the so-called *funding gap*, that is, the lack of private funding sources available to support technology transfer activities and academic spin-offs, even among more "advanced" or risk-oriented investors, such as venture capital firms or business angels (Munari and Toschi 2011; Salmenkaita and Salo 2002). As a general rule, university-generated inventions tend to be embryonic in nature and at the frontier of scientific advancements (Colyvas et al. 2002; Jensen and Thursby 2001; Munari and Toschi 2011), so they involve considerable risks in terms of their subsequent validation, industrialization, and commercialization.

Along with structural rigidities and markets' failure to provide sufficient capital in early research stages, Salmenkaita and Salo (2002) note another rationale for government intervention: *systemic failure*. Because the effectiveness of innovation systems depends on interactions among various players (e.g., companies, government laboratories, universities), different priorities, goals, and objectives can endanger their long-term performance and prompt systemic failure. Government intervention helps mitigate such systemic failures in the commercialization of new technologies by creating incentives for interactions, collaborations, and knowledge and technology exchanges among organizations, across different stages of the innovation process (Salmenkaita and Salo 2002). For example, governments might introduce technology programs aimed at promoting collaborative R&D projects between industry and academia.

Just as there are differences in the goals and priorities of various actors, expertise, cultural, and language differences arise between academics and potential users of the technology (Rogers 2002), which can create a *communication gap* in different phases of the technology transfer. This gap provides another rationale for government intervention, because poor comprehension of academic language or principles by industry players, as well as a general lack of awareness or understanding of business culture and the requirements of the commercialization process among the academic actors (Rasmussen and Rice 2012; Stankiewicz 1998), hinder knowledge and technology flows. This barrier requires intervention by a third party (i.e., the government), which can provide dedicated facilities and consulting assistance to support interactions among different actors throughout the knowledge and technology transfer process (Feldman et al. 2002).

Finally, academic literature notes the existence of a *knowledge gap*, because academic researchers and entrepreneurs might lack the managerial skills and competences needed to advance their technologies or start-ups to a point at which it is possible to negotiate successfully with industrial partners or external investors (Rasmussen and Rice 2012). This knowledge gap also might affect the personnel who staff university technology transfer offices (TTOs) or incubators, especially newly established ones; they may not have adequate education or professional experience to deal with representatives of industrial or financial worlds. Thus, necessary public policies should seek to build competence within universities, by educating university staff about the elements and details of commercialization and technology transfer.

These barriers and gaps between new knowledge generators (universities) and intended adopters (industry, public administration, society at large) have prompted actions by national and regional authorities and policy makers, which aim to increase the effectiveness of commercialization and knowledge transfers from academia to enhance their economic and social impacts (Feldman et al. 2002). Multiple academic studies focus explicitly on such public policy measures; on the basis of our review of these studies, summarized in the next section, we derive a conceptual framework for analyzing government's role in facilitating the commercialization of academic knowledge.

4 Analytical framework

For the purposes of this review, we identify two conceptual dimensions for classifying extant articles. First, we classified existing literature according to the type of public policy measure reported. Our analysis revealed analyses of three macro-level public interventions in technology transfer. *Legislative/institutional reforms* define the rules and boundaries for undertaking technology transfer activities between universities and industry actors in a country. The articles addressing such general measures dealt with university IP reforms, laws establishing the financial and organizational autonomy of universities, regulations of researchers' status, laws for establishing TTOs at universities or other supportive infrastructures, and laws to regulate university–industry collaborations. *Direct financial support measures* instead aim to close the funding gap for transferring knowledge from universities

Table 1 Conceptual framework: classification of existing academic studies

Policy measure	Focus	
	Design	Impact
Legislative/ institutional		
Intellectual property right legislation	Baldini (2006), Baldini et al. (2012), Damsgaard and Thursby (2012), Debackere and Vergeulers (2005), Gallochat (2003), Geuna and Rossi (2011), Goldfarb and Henrekson (2003), Jacob et al. (2003), Mowery and Sampat (2005), Ranga et al. (2003), Saragossi and de la Potterie (2003)	Baldini et al. (2006), Baldini et al. (2014), Damsgaard and Thursby (2012), Della Malva et al. (2008), Giuri et al. (2013), Grimaldi et al. (2011), Huelsbeck and Lehmann (2006), Iversen et al. (2007), Mowery and Sampat (2005), Valentin and Jensen (2007), von Ledebur (2009), von Ledebur et al. (2009)
Other legislation	Baldini et al. (2006, 2010), Gallochat (2003), Goldfarb and Henrekson (2003), Jacob et al. (2003), Lissoni et al. (2013), Mustar and Wright (2010)	Della Malva et al. (2008), Lissoni et al. (2013), Mustar and Wright (2010)
Financial support	Abetti (2004), Bigliardi et al. (2006), Bradley et al. (2013), Clarysse et al. (2007), Della Malva et al. (2008), Eickelpasch and Fritsch (2005), Goldfarb and Henrekson (2003), Huggins (2006), Hulsink et al. (2008), Lotta (2003), Munari and Toschi (2011), Mustar (2002), Rasmussen (2008), Rasmussen and Rice (2012), Rasmussen and Sorheim (2012), Uecke et al. (2010), van der Steen et al. (2008), Wright et al. (2006)	Borlaug et al. (2009), Link and Scott (2010, 2012, 2013), Rasmussen and Rice (2012), Toole and Czarnitzki (2005)
Competence development	Mustar (2002), Mustar and Wright (2010), Rasmussen (2008)	

to industry, through subsidies, commercialization grants, proof-of-concept or translational funds, pre-seed and seed funds, and financial aid from national or regional governments, which provide subsidies and funding programs to help establish TTOs, incubators, and science parks. In addition, a range of direct financing schemes seek to enhance university–industry collaborations. The third broad set encompasses *competence-building measures* that address knowledge gaps between academic researchers and entrepreneurs related to technology exploitation and entrepreneurship issues by providing support for training programs or competence-building programs, for university researchers, entrepreneurs, and TTO staff.

Second, we can classify existing literature according to the focus of the articles: the *design of public policy measures* to support technology transfer or the *ultimate impact of public policy measures*. The former category adopts a more descriptive approach toward the aims and features of various policies implemented in different countries. The latter set mainly assesses the effectiveness of programs using different approaches and performance indicators. Table 1 presents our classification of prior literature along these two dimensions.

As Table 1 shows, some areas of public intervention and support have received abundant attention from the academic researchers; others have lacked such attention and thus represent major gaps. In particular, a disproportionate number of papers focus on the design of university intellectual property right (IPR) reforms in various countries, following the path-breaking Bay–Dole Act in the United States (e.g., Baldini et al. 2006; Goldfarb and Henrekson 2003; Mowery and Sampat 2005). Very few studies consider other types of legislative or institutional reforms (e.g., Jacob et al. 2003; Lissoni et al. 2013; Mustar and Wright 2010). In a similar development, among studies investigating public financial measures, we find that the primary emphasis has been on describing different types of financial measures (Della Malva et al. 2008; Mustar 2002; Rasmussen 2008; Rasmussen and Sorheim 2012; Wright et al. 2006), but insufficient research evaluates the impacts of such support measures (Borlaug et al. 2009; Rasmussen and Rice 2012). Finally, we note considerable gaps in research related to the third group of public policy measures, aimed at funding competence-building initiatives or training programs (e.g., Mustar and Wright 2010; Rasmussen 2008). Although the so-called knowledge gap represents a serious barrier to the success of technology transfer activities, existing literature has almost completely neglected this government intervention and support area. Accordingly, we proceed to a more detailed discussion of these existing studies to identify, at a fine-grained level, the unaddressed questions and opportunities for research.

5 Existing evidence about public policy measures in support of technology transfer

In each of the following subsections, we provide a detailed account of a distinct set of public policy measures, according to our proposed classification.

5.1 Legislative/institutional measures

Studies that address legislative reforms introduced in different countries to promote technology transfer generally provide an overview of legislative reforms pertaining to the ownership of the patent rights or the commercialization of academic inventions and university–industry collaborations. A widely accepted notion indicates that a key catalyst for both the commercialization of university research and university–industry collaborations has been changes in legislation in various nations (Geuna and Rossi 2011). Two types of policy initiatives seemingly have accelerated the rate of knowledge and technology transfer from universities to industry: changes in IP ownership regimes in favor of universities (e.g., U.S. Bayh–Dole Act of 1980 and similar legislation in European countries; Crow and Bozeman 1998; Scott 1989) and dedicated regulations designed to stimulate research joint ventures (e.g., the U.S. Cooperative Research Act).

5.1.1 Reforms to university IPR regimes

Reforms related to the ownership of university IPRs are exemplified by the 1980 Bayh–Dole Act in the United States, which allowed universities to retain their IPR on inventions resulting from federally funded research. This Act prompted a series of similar reforms in European and other nations, which in turn led to a rich, diversified stream of economic literature on their actual consequences for patenting behavior and commercialization outcomes. For example, several studies described the implementations of these reforms in different countries, including the United Kingdom (Macdonald 2009; Meyer and Tang 2007; Tang 2008), Italy (Balconi et al. 2003; Baldini et al. 2006, 2015), Germany (Czarnitzki et al. 2011; von Ledebur 2009; von Ledebur et al. 2009), Spain (Azagra-Caro 2010; Azagra Caro et al. 2003; Cesaroni and Piccaluga 2003), Denmark (Baldini 2006), Belgium (Ranga et al. 2003; Saragossi and de la Potterie 2003), France (Azagra Caro et al. 2003; Carayol and Matt 2004; Cesaroni and Piccaluga 2003; Della Malva et al. 2008; Lissoni et al. 2008), Norway (Iversen et al. 2007), and Sweden (Thursby 2012; Jacob et al. 2003).

Although most studies indicate that these regulations gave universities greater incentives to commercialize their inventions, some researchers express doubt about whether they have substantially fostered technology transfer (e.g., Kenney and Patton 2009; Mowery et al. 2001). Several leading universities, such as the University of California or Stanford University, already had increased their patenting activities before the Bayh–Dole Act passed, and similar phenomena appeared in many European countries prior to their passage of similar regulations (Mowery et al. 2001).

Geuna and Rossi (2011), in their study of university IPR ownership regulations in Europe, argue that the general increase in the number of university-owned patents often observed after the reforms cannot be ascribed entirely to changes in university IPR legislations. The shift to university IPR ownership was accompanied by other important changes that also might have triggered more commercializing activities; for example, in the United States, the Bayh–Dole Act passed around the same time as the University and Small Business Patent Procedures Act, which enabled the federal government to arrange for the licensing of patents not exploited by academic administrations (i.e., march-in right) (Geuna and Rossi 2011). Subsequent measures extended the scope and duration of patent protections (Feldman and Stewart 2006; Jaffe 2000; Kortum and Lerner 1999) and progressively removed obstacles to commercial exploitation of findings obtained through research conducted in public laboratories (Geuna and Rossi 2011).

Additional empirical evidence also indicates that though the amount of university-invented patents increased (Baldini 2006; Baldini et al. 2006; Della Malva et al. 2008; Tang 2008), the effect of the reforms on the rate of patents with university ownership remains controversial. In studying trends of both university-owned and university-invented patents, Lissoni et al. (2013) find positive trends in university ownership of academic patents at Italian universities during 1996–2007, when important reforms took place. But these authors argue that the increased autonomy of Italian universities, which allowed them to introduce explicit IP regulations for their staff's inventions, largely led to such rise of university-owned patents, effectively neutralizing the introduction of professor's privilege.

Furthermore, very few studies note the impacts of reforms on actual commercialization rates by universities. Such limited attention is surprising; the ultimate aim of these legislative reforms was to foster the transfer of knowledge and technology from academia to industry and thereby enhance the exploitation of universities' research. Some recent exceptions published by Sterzi (2011) and Czarnitzki et al. (2011) compare the value of university-owned and university-invented patents; Crespi et al. (2010) and Giuri et al. (2013) assess the impact of university ownership on patent commercialization rates, in terms of licensing, spin-off formation, or sales. With a survey-based study of 858 university and PRO patents filed with the European Patent Office between 2003 and 2005 across 22 countries, Giuri et al. (2013) show patent ownership significantly affects commercialization, though the effect varies with the type of exploitation and the organizational context, such that ownership by public research organizations (PROs) affects patent sales and spin-off creation negatively, whereas university ownership enhances licensing. The substantial remaining gaps in scholarly assessments of the quality of reforms pertaining to IPR ownership at both country and multi-country levels demand further research along these lines, as we discuss subsequently.

5.1.2 Other legislative reforms in support of technology transfer

A more limited set of studies addresses different legislative reforms that seek to regulate a *researcher's status*. Gallochat (2003), Mustar and Wright (2010), and Clarysse et al. (2007) cite the example of France, where until 1999, academic researchers could not create their own companies to develop or exploit their research results and instead maintained a status as civil servants. A 1999 law then granted academics the right to participate—as a founder, consultant, or manager—in new companies and to take equity stakes, which greatly expanded the range of opportunities for scientists to engage in the commercialization of their research work. Geuna and Nesta (2006) highlight the multiple EU countries that granted researchers the right to receive some portion of the royalties derived from their patented discoveries, even if the IPRs belonged to the institution in which they developed the discovery. Clarysse et al. (2007) and Debackere and Vergeulers (2005) focus on Belgium and show that, along with the introduction of new legislation in 1996 that assigned universities the legal mission to commercialize their research results, the national legislative framework included new provisions that made it easier and less ambiguous for academics to start companies. However, these studies did not evaluate the impacts of such measures. Although Mustar and Wright (2010) investigate the effectiveness of France's researcher status legislation, they find no strong evidence of intensified new academic startups after the law's implementation.

Other investigated legislative measures include national laws that encourage and regulate the *creation and status of university TTOs*. Goldfarb and Henrekson (2003) report a dramatic increase in the number of TTOs in U.S. universities and argue that their creation was incentivized by the Bayh–Dole Act; once universities were granted property rights, they were motivated to implement efficient internal mechanisms to solicit disclosures by faculty and maximize their economic returns from technology transfer. In Europe, Della Malva et al. (2008) cite the example of France, where the Innovation Act of 1999 introduced the possibility that both universities and public research organizations could create internal TTOs, staff them with external personnel, and run them according to business-oriented budgetary and accounting rules. These authors indicate that establishing a TTO has a strong, significant impact on universities' decisions to retain IPR over their scientists' discoveries.

A parallel set of studies addresses legal provisions directed at fostering the creation of other infrastructure facilities for technology transfer, such as university incubators, innovation agencies, or science parks. In France, the creation of university incubators had been fostered by the Law on Innovation and Research to Promote the Creation of Innovative Technology Companies, a provision discussed by Gallochat (2003) and Mustar and Wright (2010). This Law granted universities and research institutions the opportunity to create incubators that provided premises, equipment, and other resources to faculty members who wanted to found a new company, as well as to existing young companies (Gallochat 2003). In terms of the effectiveness of the legislative measure, Gallochat (2003) reports a positive trend in the number of newly created companies at universities. However, this study followed almost immediately after the implementation of the measure, so it used a very limited time window to assess the consequences of the form. The more recent study by Mustar and Wright (2010) suggests a small and decreasing number of academic spinoffs in France, leading them to propose that the suboptimal impact of legal policy measures has resulted from underestimations of both the necessary time scales from the funding authorities and the difficulty of the learning process for newly established structures and their management staff, as well as difficulties with changing cultures and attitudes in well-established organizations, such as universities.

Legislative measures directed at establishing *university autonomy* seek to lower their reliance on public funding and thus encourage their solicitation of additional resources from industry, through technology transfer and commercialization activities (Baldini et al. 2006, 2012; Lissoni et al. 2013; Lissoni 2012; Reale and Poti 2009). The design, implementation, and effectiveness of such legislative reforms, which were widely implemented in Italy, are the focus of studies by Baldini et al. (2006, 2012, 2014) and Lissoni (2012). In response to the introduction of autonomy and accountability principles for university governance (Reale and Poti 2009), Italian science-oriented universities established explicit internal IPR regulations and created internal mechanisms to support commercialization and technology transfer (Baldini et al. 2012). Lissoni et al. (2013) also report a positive impact of university autonomy on domestic patenting by Italian academic inventors. This public measure increased the number of university-owned patents, because autonomy encouraged universities to be more proactive in managing the results obtained by their employees, in that they retained a share of the IPR over these inventions during any subsequent commercialization.

Finally, some legislative acts and regulations have provided specific measures to *promote university–industry collaboration*, usually through tax deduction schemes. They vary from country to country in terms of their specific characteristics, but the rationale for such measures is similar: to provide incentives for industry actors to engage in collaborative research and commercialization projects with academia. Among the most well-known of these legislative measures is the U.S. Cooperative Research Act. Several authors report a positive effect of this Act on the number of links between industry and academia (Crow and Bozeman 1998; Scott 1989).

5.2 Direct financial measures

5.2.1 Commercialization grants/subsidies

In addition to creating favorable legislative environments for enhanced commercialization of academic inventions, university–industry collaborations, and spin-off formation, national governments and regional authorities adopt various public policy measures to provide financial and other forms of assistance to universities and research institutions, to help them move toward commercialization. Other measures seek to encourage venture capital and business communities to participate actively in technology transfer processes.

In turn, some studies investigate publicly funded programs aimed at assisting universities in shifting to commercialization and engaging more smoothly in technology transfer or cooperating with industry (e.g., Clarysse et al. 2007; Rasmussen 2008; Rasmussen and Rice 2012; Wright et al. 2006). Rasmussen (2008) provides a detailed account of one of the most important federal-level initiatives for accelerating knowledge and technology transfer from local universities in Canada, namely, the Intellectual Property Mobilization program (IPM). The IPM grants were intended to strengthen the ability of Canadian universities to manage their IP, attract potential users, and promote the professional development of IP personnel through networking approaches (Rasmussen 2008). Borlaug et al. (2009) report on the FORNY program in Norway, considered the main support mechanism for the commercialization of publicly funded research in that country. Established during the 1990s, it targets university TTOs instead of researchers directly. Borlaug et al. (2009) note the significant government efforts to build an entrepreneurial culture in academia and foster technology transfer; they also highlight that many Norwegian initiatives resulted from experimentation and collaborations with local-level actors. As the infrastructure grew more developed at institutional and regional levels, the need for federal-level government intervention decreased. Rasmussen and Rice (2012) also consider the case of Norway, specifying that its development of efficient policy initiatives followed a bottom-up approach, working closely with local actors and taking into consideration their current operational needs.

Another interesting perspective on this type of public measures comes from Toole and Czarnitzki (2005), who analyze the U.S. Small Business Innovation Research (SBIR) program, a policy action to foster academic entrepreneurship. They find evidence of the certification hypothesis proposed by Lerner (1999), in that academic start-ups that completed the SBIR program were more likely to receive follow-up venture capital funding. Link and Scott (2010, 2012, 2013) provide further evidence of economic and employment benefits of SBIR programs. Although the direct impact of SBIR-funded projects on employment is small on average, substantial cross-project differences in the number of retained employees reflect differences among firms and their SBIR projects. For example, projects that leverage IPRs or serve the government as a client invoked a greater employment stimulus (Link and Scott 2012).

Eickelpasch and Fritsch (2005) explore field-specific commercialization grants in Germany by investigating the Bioregio program, designed to provide financial support for project commercialization in the biotechnology field. They argue that this type of policy can have significant impacts and should be regarded as an efficient instrument of public support for technology transfer from university to industry.

Another group of academic studies looks at *grants targeted at individual researchers*. For example, Rasmussen and Rice (2012) and Rasmussen and Sorheim (2012) report on

FORNY-provided leave-of-absence grants in Norway, which cover researchers' salaries if the employer makes 20–100 % of the position duties responsible for commercialization projects, and the Enterprise Fellowship Program in Scotland, which helps individual academic researchers develop spin-offs by covering 12 months of their salary while they develop the idea (and undertake business training) and providing important links to networks of business angels. Clarysse et al. (2007) analyze both Germany's EEF Fund, which grants scholarships to individual researchers to start spin-offs, and Belgium's unique spin-off post-doctoral grants for spin-off funding. Other Belgian universities (e.g., Ghent, Antwerp) receive *government-funded mobility scholarships* that allow post-doctoral researchers to find employment in their research field but still leave the option of returning to the university open (Clarysse et al. 2007).

5.2.2 Seed funding

In most countries, public authorities set up seed capital funds to overcome funding gaps resulting from a general reluctance among private venture capital (VC) investors to finance the early phases of university-initiated start-ups (Clarysse et al. 2007; Lockett et al. 2002; Moray and Clarysse 2005; Munari and Toschi 2011, 2015; Wright et al. 2006). Studies by Knockaert et al. (2010) on a sample of start-ups from various European countries and by Munari and Toschi (2011) on a sample of new ventures from the micro- and nanotechnology sector in the United Kingdom reveal that, in contrast with purely private VC funds, publicly funded VCs tend invest more in early-stage university start-ups, in empirical support of governments' efforts to bridge the funding gap (Rasmussen and Sorheim 2012). Yet as Rasmussen and Sorheim (2012) caution, even as public funds have become increasing important sources of early-stage funding for university start-ups, little systematic research has investigated the range of government funding initiatives and their impact on the growth and success of the funded university spin-offs.

Instead, most existing studies in this area offer descriptive accounts of policy interventions to establish university-oriented seed funds. Wright et al. (2006) classify existing public financing measures in Europe on the basis of the amount of public participation, such that they suggest distinguishing between 100 % publicly owned funds focused on pre-seed and seed stages (e.g., Twinning Growth Fund and Biopartner in the Netherlands; Danish Growth Fund in Denmark; Fond de Co-investissiment des Jeunes in France) and public–private partnerships in which public participation varies from 10 % to more 90 %, depending on the country. They also find evidence of a severe mismatch between the demand and supply sides of the venture capital market.

In the United Kingdom, the University Challenge Fund is arguably the most famous public policy initiative to foster technology transfer by establishing seed capital funds, also known as Challenge Funds, that encourage the exploitation of scientific discoveries in universities (Mustar and Wright 2010). In Belgium, Wright et al. (2006) report that the universities of Ghent, Brussels, and Antwerp each have respective seed capital funds worth more than $2.5–5 million at their disposal to invest in spin-offs. In 2005, a Flemish initiative, similar to the SBIR, allowed the funds to increase their capital with equal amounts of public money. In France (Mustar and Wright 2010), public grants to fund the creation of academic spin-offs generally have been obtained through a national competition that identifies the best projects and awards them grants. These projects then could be hosted in public incubators; after their official creation, they could receive further financing from seed money funds (Mustar and Wright 2010). In Norway, with joint seed capital funds between the government and private investors, the government provides loans as a risk-reduction mechanism, and private investors provide equity capital (Rasmussen and Rice 2012). The goal is to stimulate private investors to invest in early phases of new venture development, as well as share their competences with the new firms.

In contrast, Lotta (2003) reports the concern that overly extensive public sector activity may have a "crowding out" effect on private businesses, such as the markets for startup consultants or service providers. This author argues that the government instead should focus on providing support and services in areas not covered by existing markets, such as the collection, systematization, and dissemination of information or the coordination of programs that can increase networking among players in an innovation cycle.

As this review demonstrates, no academic study has addressed in detail the governance and design of publicly supported university seed funds, their investment strategies, or their ultimate impact. Research designed specifically to address the issues of the effectiveness of the financing measures thus is critical.[1]

5.2.3 Proof-of-concept funds

A set of mechanisms recently has emerged in several countries, under the label "proof-of-concept funds" (PCF) or similar names (e.g., translational funds, pre-seed funds, proof-of-principle fund, fonds de maturation; Bradley et al. 2013; Gulbranson and Audretsch 2008; Maia and Cara 2013). These instruments focus on the early stages of the technology transfer process, to identify technologies that could be applied in new products and services and prepare for the actual transfer of technology or knowledge. A PCF typically provides funding to a project to assess its commercial potential, demonstrate the feasibility and value of the technology, facilitate the definition of the business plan or strategic plans, and encourage the formation and registration of a new company. In addition to direct financial support, many PCF programs establish comprehensive frameworks for enhancing the effectiveness of early-stage technology transfer processes, by adding facilities, management expertise, legal advice, or mentoring.

Although literature on these emerging instruments is growing, scant attention acknowledges the public policies that have been implemented to enhance their establishment and diffusion. In an early study, Rasmussen (2008) discusses policy initiatives in Canada, where general agencies such as the Industrial Research Assistance Program and the Business Development Bank of Canada provide considerable PCF to university research teams. Many Canadian university spin-offs have received such support, which specifically targets projects carried out in cooperation between academics and companies. The author cites the general positive impact of this public policy measure, reporting that spin-offs that received government support generally performed better, and 72 % of the supported start-ups subsequently received VC funding, compared with 44 % in the overall sample. In a subsequent study, Rasmussen and Sorheim (2012) analyzed another dedicated government grant program in Canada that provides financing to help turn discoveries and inventions into commercializable technologies. This funding opportunity focuses on individual researchers, to enable them to move their discovery further along the innovation pipeline. A similar program in Scotland provides funding for pre-commercialization phases; approximately £28.1 million has been awarded to 172 projects since 1999, though the authors

[1] A recente exception is represented by the study by Munari et al. (2015) analyzing the impact of university-oriented seed funds in Europe. This study, however, does not consider in detail the sources of capital (public vs. private) for such funds.

have no evidence about the subsequent success of projects that received financing (Rasmussen and Sorheim 2012).

Hulsink et al. (2008) describe the entrepreneurship stimulation program TechnoPartner, set up by the government of the Netherlands in 2004 to promote knowledge and technology transfer through spin-off creation by universities and research institutes. It aims to address the financial and information-related obstacles academic spin-offs may encounter (e.g., improving markets for seed and early stage financing, providing specific information and advice to academic researchers). Uecke et al. (2010) instead analyze “ForMaT–Research within a Team for the Market,” a program initiated by the German federal ministry for education and research to foster knowledge and technology transfer. By providing a means to evaluate potential early and thus spur the innovation process, programs such as ForMaT also establish criteria for enhancing the effectiveness of the early stages of invention and technology transfer processes.

In general, the impact of public policy measures aimed at addressing the early financing gap appears positive. Using survey data, Huggins (2006) tests whether private sector seed funding for knowledge commercialization is more likely if public funding is already in place and find that universities that gain significant public funding are more likely to access private funding. With their review, Borlaug et al. (2009) similarly show that academic start-ups that demonstrate greater commercial success tend to be better endowed with public financing through dedicated government schemes and seed fund investments. The presence of early-stage public sector funding seemingly acts as a signal for private sector involvement, such that the probability of receiving private sector investment increases with the amount of public funding secured, due to the reduced risks of involvement and the apparent legitimacy of the investment (Leleux and Surlemont 2003).

However, other studies highlight the potential drawbacks of pre-seed and seed funding of academic start-ups. For example, providing public capital to create an academic spin-off may lead to an overvaluation of the IP during the start-up phase, as reflected in the amount of capital required to create such spin-offs. Clarysse et al. (2007) argue that this overvaluation does not have positive effects on the short-term performance of the spin-offs (measured by raised capital in a post–start-up stage). Another concern is that the prior use of public funding increases not the probability of private-sector investments but rather the likelihood of continuing public funds (Lotta 2003). These questions call for additional analyses and empirical evidence regarding the effectiveness of existing public PCF and seed financing measures for the commercialization of university inventions.

5.2.4 Policies to create TTO facilities and infrastructures

Another type of public policy measures, extensively covered in existing academic literature, refers to *financing the establishment and development of technology transfer offices and infrastructure*. In line with legislative changes, several European governments started subsidizing “interface” services such as TTOs to help establish or develop their activities (van Zeebroeck et al. 2008; Wright and Filatotchev 2008). Lissoni et al. (2008) provide the example of Denmark, where the government provided substantial funding for the creation of a technology transfer infrastructure following the introduction of institutional ownership measures. In addition to financing the initial creation of a TTO at local universities, some countries (e.g., Norway, France, Germany, Belgium) seek to stimulate the professionalization of TTOs. In particular, national or regional institutions and universities in some countries grant TTOs extra funding so they can apply for patents or provide incubation services to potential spin-offs (Clarysse et al. 2007). Extant research indicates that beyond their expected impact, such measures increased the importance attached to patents and IP generally (Clarysse et al. 2007; Wright and Filatotchev 2008).

A related form of government support provides financial aid to university *incubators* and *science parks*, most of which have directly links to universities (Wright et al. 2006). This approach thus represents another viable public policy measure, aimed at facilitating commercialization of university inventions. Jacob et al. (2003) report that in the late 1990s, France and Sweden launched National Incubation Programs to decrease the knowledge gap and facilitate technology entrepreneurs' efforts to start up their businesses. The academic spin-offs that enrolled in these programs benefited from business support and low cost facilities. In addition, various organizations to support technology transfer were established during the 1990s in Sweden, with support from public funding, including a series of technology bridging foundations (Teknikbrostiftelser) that helped universities build links with industry and other stakeholders; a more recent development focuses on national competence centers, financed jointly by industry, university, and government (Jacob et al. 2003). In a study of French incubators, Mustar (2002) reports that at the end of 2001, 31 incubators had already hosted 440 projects, more than half of which won publicly funded national business creation competitions. Abetti (2004), addressing the case of Finland, shows that for almost three decades, the government supported the development of an extensive network of business incubators and provided support for the training of incubator managers with a multi-year grant from the Ministry of International Trade and Industry. This proactive approach to funding and incentivizing incubators in Finland appears to enhance not only university technology transfer but also economic growth and entrepreneurship on a broader scale (Abetti 2004). Furthermore, Borlaug et al. (2009) and Rasmussen and Rice (2012) explain how the Norwegian government participated in the funding of university incubators and science parks connected to large research institutions, through its SIVA agency, which acted as a part owner of infrastructure initiatives. The debate about the effectiveness of such measures continues though. For example, Aernoudt (2004) reports that no U.S. technology incubators in 2004 (including those established in the early 1980s) had achieved full financial self-reliance.

Science parks are another type of support infrastructure; they usually locate close to universities and receive substantial public funding. In Italy, most financial support for Italian science parks comes from public sources (e.g., Scientific Park of Trieste, VEGA science park, Galileo; Bigliardi et al. 2006). Some scholars underline the critical role of science parks, as support mechanisms for academic start-ups, yet a recent debate questions whether these infrastructure facilities actually represent efficient tools for enhancing start-up performance (Cooper 1973, 1984; Meyer 2003). The results of a study performed in the United Kingdom demonstrate that science park firms report slightly higher research productivity than comparable firms not located in these facilities, measured by new products, services, and patents (Siegel et al. 2003). Another major concern relates to exit rates from the science parks, which tend to remain low. Phan et al. (2005) and Vohora et al. (2004) argue that the reason for these low exit rates may be existing incentive systems, which encourage science park managers to maintain full occupation capacity. The most obvious issues for the effectiveness of infrastructure initiatives thus are governance questions, related to the appropriate incentives and measures of science park or incubator performance, and the availability of organizational capabilities to help tenant firms develop to an "exit" point (Phan et al. 2005; Vohora et al. 2004).

Phan et al. (2005) also highlight that, because incubators and science parks often result from public–private partnerships, multiple principals have some say, which may lead to a principal–principal agency problems and opportunistic behavior by controlling shareholders. To the extent that the principles of good corporate governance are neither formalized nor embedded in the management routines of science parks and incubators, the principal–principal conflict may lead to inefficient resource allocation decisions by incubator and park administrators, which in turn decrease the efficiency and performance of their resident organizations (Phan et al. 2005).

Despite these questions about their actual efficiency and effectiveness, academic literature concurs that a key benefit of science parks and incubators for academic start-ups is the professional assistance they provide in spotting and joining established business networks. This benefit takes on particular relevance because, as various researchers assert, the ability to access external finance through networks is a central predictor of start-up firms' performance (Elfring and Hulsink 2003; Lee et al. 2001).

In summary, in addition to their primary role of encouraging technology transfer from university or R&D laboratories to high-tech entrepreneurial startups, support structures such as incubators, science parks, and so forth provide for job creation, regional economic development, and export promotion. However, only limited empirical evidence describes their actual contributions to successful knowledge transfer and economic development, suggesting the need for further, more in-depth research on their actual impact.

5.2.5 Financing university–industry collaboration

To foster technology transfer and commercialization of university knowledge, another important tool is public support for university–industry research and technology partnerships (Bozeman and Gaughan 2007). With such public policy measures, national or regional governments can promote a fruitful, interdisciplinary framework for technology transfer processes (Uecke et al. 2010). In the United States, some of the most cited programs are the Small Business Administration's Innovation Research program (Audretsch et al. 2002), Small Business Technology Transfer research grants that provide support to cooperative early-stage R&D efforts between a small enterprise and a university partner (Wright and Filatotchev 2008), the Cooperative Research Act (Crow and Bozeman 1998; Scott 1989), and the National Science Foundation's industry–university cooperative research centers program (Feller et al. 2002; Gray and Walters 1998). In Europe, research considers the LINK scheme, established in the United Kingdom in 1986 to support collaborative research and development projects between industry and universities in strategically important areas, and Knowledge Transfer Partnerships, introduced in 2004 to help companies gain access to the knowledge, resources, and expertise available in universities so they could develop new products and working processes (Mustar and Wright 2010). Another example, presented by Van Looy et al. (2003), is Germany's soft R&D loan schemes, seeking to instill cooperative links between academia and industry. In the Netherlands, Hulsink et al. (2008) provide evidence about Subsidy Regulation Infrastructure Techno-starters, an initiative that provides subsidies to knowledge institutions when they support new technology firms.

More limited attention in academic literature addresses *tax deduction schemes* as fiscal instruments to support collaborations. Rasmussen and Rice (2012) note the Skattefunn action in Norway, designed such that the level of reimbursement for R&D expenses, in the form of tax deductions or direct grants, increases when a research institution is involved.

Policy measures to induce collaboration between universities and industry also rely on so-called *technology programs*. In Finland, the Tekes technology programs of the National Technology Agency favor collaborative projects, that is, those submitted by universities but supported by one or more industrial partners or those run by large firms that establish subcontracts with universities (Salmenkaita and Salo 2002). The German EXIST program, introduced in 1997 (Eickelpasch and Fritsch 2005), aims to improve knowledge transfers between universities and the commercial sector by promoting entrepreneurship and encouraging the creation of start-ups by students and academic personnel.

Despite the clear value-adding objective of bringing incentive structures of academia and industry closer in line through collaboration, the overall effectiveness of these programs remains in doubt. As Salmenkaita and Salo (2002) note, technology programs often invoke strong critiques for their rigid structures and premature selection of technological options that could hinder their overall effectiveness. Such programs also tend to favor R&D activities in established rather than emerging industries, which is a short-sighted approach that conflicts with the program's ultimate goals and could have negative impacts on national innovation systems over time (Salmenkaita and Salo 2002). Quantitative assessments of the ultimate impact of such programs are missing from extant literature, which mostly relies on descriptive or anecdotal evidence. It is therefore difficult to infer any concrete guidelines for the optimal design of such measures.

5.3 Competence-building measures

The final group of public policy measures aims to address the so-called knowledge gap by training academic researchers and TTO personnel about aspects of technology transfer and commercialization. National and regional funds allocated to such competence-building programs support either independent programs or more general programs designed to encourage innovation and entrepreneurship. However, we uncovered very few studies that investigate these measures. Some examples of relevant studied policy measures include the Danish Action Plan for Entrepreneurship, the SPINNO Training Program in Finland, and the Science Enterprise Challenge in the United Kingdom, which fund universities (Mustar 2002). The previously discussed IPM measures in Canada (Rasmussen 2008) launched and sponsored technology transfer internship programs that were available only to consortia of universities, colleges, or hospitals, possibly in collaboration with non-academic organizations. Other Canadian government programs crafted to increase commercialization knowledge and skills among spin-off managers and TTO staff include the Science to Business program, which encourages recent research PhDs to pursue MBAs, and the Commercialization Management Grant program, through which TTOs can recruit recent MBAs to help commercialize IP resulting from publicly funded research (Rasmussen 2008).

Mustar and Wright (2010) discuss similar measures in the United Kingdom, such as the 2005 Medici Fellowship Scheme to address the lack of effective communication between academia and industry through 50 fellowships. To encourage the commercialization of biomedical research conducted by five U.K. universities, these fellowships provided commercial training and encouraged fellows to develop links with practitioners from the biotech business community and other external stakeholders. Another public policy measure sought to instill an entrepreneurial culture among academics and legitimize academic entrepreneurship as a career choice; this Science Enterprise Challenge initiative was established by the U.K. government in 1999 (Mustar and Wright 2010). It attempted to provide potential academic entrepreneurs with contacts to members of the finance community (e.g., seed funds, venture capitalists, business angels), as well as access to science park accommodations. As Mustar and Wright (2010) highlight, such publicly supported schemes can have a crucial role in the development of links with industry players for collaborative activities, such as mentoring schemes, seminars and master classes delivered by practitioners, or sponsorships of business plan competitions at universities. However, we found no academic studies that addressed the effectiveness of such support measures. This question demands more research attention and suggests an important avenue for research.

6 Discussion, implications, and further research

Various public measures in support of technology transfer have spurred a general increase in the number of academic spin-offs and other forms of technology transfer activities in the past two decades (Clarysse et al. 2007). With this review, we have sought to classify and summarize existing literature on such policy measures, so as to take stock of the lessons learned and highlight the overlooked questions that remain. Our review reveals a series of important gaps and issues to consider with regard to the design and impact of government support in this domain.

A strong imbalance marks the research attention devoted to various types of policy measures. Whereas some actions have been investigated by many contributions, such as reforms of university IPR regimes, others have received only scant attention. The design, characteristics, and effectiveness of other legislative measures, beyond those related to the ownership of university IPRs, need to be investigated in much more depth. In particular, research should consider the degree of autonomy of universities or the legal status of researchers and TTO managers. In relation to reforms of university IPRs, studies instead should address their impact on the actual commercialization rates of academic patents (e.g., commercial uses through licensing, sale, or spin-off formation) and their overall effects in terms of innovation and economic development.

Another promising research direction would be to assess the impact of specific funding-related initiatives (e.g., seed funds, subsidy schemes, PCF). For example, does the impact of policy measures vary according to the level of implementation (national/regional/local), the degree of involvement of universities or PROs (i.e., direct management or not), the level of the target beneficiaries (e.g., TTOs, academic spin-offs, individual researchers), or the context? Considering the lack of research into competence-building measures, we also call for more attention devoted to analyses of the optimal structure of this type of public support actions, along with detailed assessments of their impact.

Another clear imbalance we found in our review pertains to the focus on to policy designs, rather than actual impacts in terms of commercialization rates, innovation, economic development, societal benefits, or job creation. A considerable body of literature already provides detailed descriptions of the design and characteristics of measures designed to support technology transfer; far fewer studies are dedicated to the evaluation of their impact and relative effectiveness. One of the reasons for this gap may be the relatively recent character of many policies, making it difficult to obtain relevant track records or perform effective evaluations of their impact (Mustar and Wright 2010). It is therefore worthwhile to discuss this issue in more depth. In particular, we posit that this gap arises for different reasons, which in turn represent opportunities and challenges for research. For example, disentangling the effects of a single public policy intervention is challenging, because multiple government measures tend to be implemented in parallel. This difficulty clearly emerges in studies of the changes brought about by IPR reforms, which often are accompanied by other measures, such as the creation of TTOs or funding to foster academic patenting (Geuna and Rossi 2011). Thus, researchers must adopt a *comprehensive,* *integrative approach* to judge the impact of government support measures, considering the long-term impacts of all the measures being implemented, as well as the interactions of both legislative/institutional and direct/financial measures.

Another methodological issue pertains to assessments of the relative impact of government policy measures. For example, it is virtually impossible to achieve a comprehensive assessment of the outcomes of technology transfer activities based solely on quantitative measures (e.g., number of patents, licenses, spin-off firms, revenues) (Rasmussen and Rice 2012). A vast range of other, non-market modes of interaction between academia and industry exist (e.g., consulting, graduated students, informal spillovers), and determining whether they exist as a consequence of public policy actions is difficult. This point highlights the need for research to develop more precise and comprehensive evaluation criteria and thus obtain a more precise, better measured assessment of the effectiveness of different public policy measures.

The assessment of public support measures also must account for differences in the institutional contexts and historical paths of public support for academic entrepreneurship and technology transfer, varied designs of policy measures, and divergent amounts of available resources, as well as the interaction of these factors with the nation's general innovation policy (Wright et al. 2006). This point also highlights the potential *complementarity* of measures targeting various levels (e.g., national, regional, local). To mitigate the risk of fragmentation in policy implementation and resource allocation (Munari and Toschi 2015), policy makers need to craft specific measures and design support mechanisms that address the complementary nature of their policies and thereby ensure more coherence and synergy in their implementation. A vast range of public policy measures undertaken simultaneously at many levels (national, regional, local) could create confusion (e.g., Rasmussen 2008) and result in the fragmentation of financial resources (i.e., too many programs of limited size and impact), as well as the potential for overlap among various programs and schemes, ultimately reducing the effectiveness of such measures (Lotta 2003). A comprehensive approach to policy formulation and implementation is necessary, by designing and implementing a *coherent overall strategy* that can enhance technology transfer and the commercialization of university knowledge.

The general lack of research on the impact of public policy measures may stem from the difficulty associated with obtaining the necessary data to perform such evaluations. Public authorities at international (e.g., EU Commission), national, and regional levels should facilitate the construction and consolidation of complete, systematic, reliable, and comparable data sets about the third-mission activities undertaken by universities and PROs. This major step would enable cross-country comparisons of the effectiveness of policy measures for technology transfer.

The preceding shortcomings have forced policy makers to design and implement public measures for technology transfer by relying on benchmarking and experimentation, instead of solid conceptual frameworks or evidence-based insights (Geuna and Muscio 2009). Researchers have a long way to go to integrate disparate practices into conceptual frameworks that can recommend ways to enhance the performance of these programs and improve the returns on investments of government resources (Rasmussen and Rice 2012).

Finally, taking all our findings into consideration, we offer several implications for national governments and public policy makers regarding the design, implementation, and assessment of measures to support technology transfer. First, they need a comprehensive, integrated approach toward policy formulation and implementation (legislative framework, funding, competences), striving for coherence and synergy across national, regional, local, and university-level policies and measures. Second, to address the inherent institutional differences and path dependencies, tailor-made solutions are required, featuring dynamic, flexible sets of initiatives that can shift with the constant changes in operational settings (Rasmussen 2008). Third, policy makers should demand and rely on better fitting, more precise indicators to account for the interplay of the full array of knowledge transfer channels and mechanisms (Mowery and Sampat 2005). In this sense, making timely data widely available to researchers, university administrators, and policy makers is an important prerequisite of accurate assessments of the impact of public policy measures and a key input for benchmarking exercises that seek to identify successful experiences and best practices to build on in the future.

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References

Abetti, P. A. (2004). Government-supported incubators in the Helsinki region, Finland: Infrastructure, results, and best practices. *Journal of Technology Transfer, 29*(1), 19–40.

Aernoudt, R. (2004). Incubators: Tool for entrepreneurship? *Small Business Economics, 23*, 127–135.

Audretsch, D. B., Link, A. N., & Scott, J. T. (2002). Public/private technology partnerships: Evaluating SBIR-supported research. *Research Policy, 31*, 145–158.

Azagra Caro, J. M., De Lucio, I. F., & Gracia, A. G. (2003). University patents: Output and input indicators… of what? *Research Evaluation, 12*, 5–16.

Azagra-Caro, J. (2010). Do public research organisations own most patents invented by their staff? *Science and Public Policy, 38*(3), 237–250.

Balconi, M., Borghini, S., & Moisello, A. (2003). Ivory tower vs. spanning university: il caso dell'Universita di Pavia. In A. Bonaccorsi (Ed.), *Il Sistema della Ricerca Pubblica in Italia* (pp. 133–175). Milan: Franco Angeli.

Baldini, N. (2006). The act on inventions at public research institutions: Danish universities' patenting activity. *Scientometrics, 69*(2), 387–407.

Baldini, N., Fini, R., & Grimaldi, R. (2012). *The transition towards entrepreneurial universities: An assessment of academic entrepreneurship in Italy*. Available at SSRN: http://ssrn.com/abstract=1979450 or doi:10.2139/ssrn.1979450

Baldini, N., Fini, R., Grimaldi, R., & Sobrero, M. (2010). *The institutionalisation of university patenting activity in Italy. Diffusion and evolution of organisational practices.* SSRN—id1632430 paper.

Baldini, N., Fini, R., Grimaldi, R., & Sobrero, M. (2014). Organisational change and the institutionalisation of university patenting activity in Italy. *Minerva, 52*, 27–53.

Baldini, N., Grimaldi, R., & Sobrero, M. (2006). Institutional changes and the commercialization of academic knowledge: A study of Italian universities' patenting activities between 1965 and 2002. *Research Policy, 35*(4), 518–532.

Bigliardi, B., Dormio, A. I., Nosella, A., & Petroni, G. (2006). Assessing science parks' performances: Directions from selected Italian case studies. *Technovation, 26*, 489–505.

Borlaug, S. B., Grünfeld, L., Gulbrandsen, M., Rasmussen, E., Rønning, L., Spilling, O. R., & Vinogradov, E. (2009). *Between entrepreneurship and technology transfer: Evaluation of the FORNY programme*. In Rapport/NIFU STEP; 19/2009, NIFU STEP, Oslo, p. 160.

Bozeman, B. (2000). Technology transfer and public policy: A review of research and theory. *Research Policy, 29*, 627–655.

Bozeman, B., & Gaughan, M. (2007). Impacts of grants and contracts on academic researchers' interactions with industry. *Research Policy, 36*(5), 694–707.

Bradley, S. R., Hayter, C. S., & Link, A. N. (2013). Proof of concept centers in the United States: An exploratory look. *Journal of Technology Transfer, 38*(4), 349–381.

Calderini, M., Garrone, P., & Sobrero, M. (2003). *Corporate governance, market structure, and innovation.* Cheltenham, UK: Edward Elgar Publishing.

Carayol, N., & Matt, M. (2004). Does research organization influence academic production? Laboratory level evidence from a large European university. *Research Policy, 33*, 1081–1102.

Cesaroni, F., & Piccaluga, A. (2003). *Universities and intellectual property rights in Southern European countries*. New York: Mimeo.
Clarysse, B., Wright, M., Lockett, A., Mustar, P., & Knockaert, M. (2007). Academic spin-offs, formal technology transfer and capital raising. *Industrial and Corporate Change, 16*(4), 609–640.
Colyvas, J., Crow, M., Gelijns, A., Mazzoleni, R., Nelson, R. R., Rosenberg, N., & Sampat, B. N. (2002). How do university inventions get into practice? *Management Science, 48*(1), 61–72.
Cooper, A. C. (1973). Technical entrepreneurship: What do we know? *R&D Management, 3* (2).
Cooper, A. C. (1984). *Contrasts in the role of incubator organizations in the founding of growth-oriented companies. Frontiers of entrepreneurship research*. Babson Park: Babson College.
Crespi, G., Geuna, A., Nomaler, O., & Verspagen, B. (2010). University IPRs and knowledge transfer: Is university ownership more efficient? *Economics of Innovation and New Technology, 19*(7).
Crow, M., & Bozeman, B. (1998). *Limited by design: R&D laboratories in the US national innovation system*. New York: Columbia Univ. Press.
Czarnitzki, D., Hussinger, K., & Schneider, C. (2011). Commercializing academic research: The quality of faculty patenting. *Industrial and Corporate Change, 20*(5), 1403–1437.
Damsgaard E. F., & Thursby, M. C. (2012). *University entrepreneurship and professor privilege.* NBER Working Paper no. 17980. http://www.nber.org/papers/w17980
Debackere, K., & Vergeulers, R. (2005). The role of academic technology transfer organizations in improving industry science links. *Research Policy, 34*, 321–342.
Della Malva, A., Lissoni, F., & Llerena, P. (2008). *Institutional change and academic patenting: French universities and the Innovation Act of 1999. University* of Strasbourg: Working Papers of BETA, no. 2008-09.
Eickelpasch, A., & Fritsch, M. (2005). Contests for cooperation—A new approach in German innovation policy. *Research Policy, 34*, 1269–1282.
Elfring, T., & Hulsink, W. (2003). *Networks in Entrepreneurship: The case of high-technology firms.* ERIM Report Series Research in Management ERS-2001-28-STR.
Etzkowitz, H., Webster, A., Gebhardt, C., & Cantisano Terra, B. R. (2000). The future of the university and the university of the future: Evolution of ivory tower to entrepreneurial paradigm. *Research Policy, 29*, 313–330.
Feldman, M., Link, A., & Siegel, D. (2002). *The Economics of science and technology: An overview of initiatives to foster innovation, entrepreneurship, and economic growth*. Boston: Kluwer Academic Publishers.
Feldman, M., & Stewart, I. (2006). *Knowledge transfer and innovation: A review of the policy relevant literature.* Prepared for the Ontario Ministry of Research and Innovation.
Feller, I., Ailes, C. P., & Roessner, J. D. (2002). Impacts of research universities on technological innovation in industry: Evidence from engineering research centers. *Research Policy, 31*, 457–474.
Gallochat, A. (2003). *French technology transfer and ip policies.* In: OECD (2003) Turning Science into Business. Patenting and Licensing at Public Research Organizations, Organisation for Economic Cooperation and Development, Paris.
Geuna, A. (1998). Determinants of university participation in EU-funded R&D cooperative projects. *Research Policy, 26*, 677–687.
Geuna, A., & Muscio, A. (2009). The governance of university knowledge transfer: A critical review of the literature. *Minerva, 47*(1), 93–114.
Geuna, A., & Nesta, L. J. (2006). University patenting and its effects on academic research: The emerging European evidence. *Research Policy, 35*, 790–807.
Geuna, A., & Rossi, F. (2011). Changes to university IPR regulations in Europe and the impact on academic patenting. *Research Policy, 40*, 1068–1076.
Giuri, P., Munari, F., & Pasquini, M. (2013). What determines university patent commercialization? Empirical evidence on the role of university IPR ownership. *Industry and Innovation, 20*(5).
Goldfarb, B., & Henrekson, M. (2003). Bottom-up versus top-down policies towards the commercialization of university intellectual property. *Research Policy, 32*, 639–658.
Gray, D. O., & Walters, S. G. (1998). *Managing the industry/university cooperative research centers. A Guide for directors and other stakeholders*. Columbus–Richland: Battelle Press.
Grimaldi, R., Kenney, M., Siegel, D. S., & Wright, M. (2011). 30 years after Bayh–Dole: Reassessing academic entrepreneurship. *Research Policy, 40*, 1045–1057.
Gulbrandsen, M., & Slipersæter, S. (2007). The third mission and the entrepreneurial university model. In A. Bonaccorsi & C. Daraio (Eds.), *Universities and strategic knowledge creation: Specialization and performance in Europe* (pp. 112–143). Cheltenham: Edward Elgar.
Gulbranson, C. A., & Audretsch, D. B. (2008). Proof of concept centers: Accelerating the commercialization of university innovation. *Journal of Technology Transfer, 33*(2), 249–258.

Huelsbeck, M. & Lehmann, E. (2006): *German university patenting and licensing: Legally prescribed incentives and institutional determinants of university–industry-technology-transfer*. DRUID-DIME Academy Winter Conference 2007 Paper.

Huggins, R. (2006). *Universities and knowledge-based venturing: Finance, management and networks in London*. Paper for the DRU9ID Summer Conference 2006.

Hulsink, W., Suddle, K., & Hessels, J. (2008). *Science and technology-based regional entrepreneurship in the Netherlands: Building support structures for business creation and growth entrepreneurship*. ERIM Report Series Research in Management ERS-2008-048-ORG.

Iversen, E. J., Gulbrandsen, M., & Klitkou, A. (2007). A baseline for the impact of academic patenting legislation in Norway. *Scientometrics, 70*, 393–414.

Jacob, M., Lundqvist, M., & Hellsmark, H. (2003). Entrepreneurial transformations in the Swedish University system: The case of Chalmers University of Technology. *Research Policy, 32*(9), 1555–1568.

Jaffe, A. (2000). The U.S. patent system in transition: Policy innovation and the innovation process. *Research Policy, 29*, 531–557.

Jensen, R., & Thursby, M. (2001). Proofs and prototypes for sale: The licensing of university inventions. *American Economic Review, 91*(1), 240–259.

Kenney, M., & Patton, D. (2009). Reconsidering the Bayh–Dole Act and the current university invention ownership model. *Research Policy, 38*, 1407–1422.

Knockaert, M., Wright, M., Clarysse, B., & Lockett, A. (2010). Agency and similarity effects and the VC's attitude towards academic spin-out investing. *Journal of Technology Transfer, 35*, 567–584.

Kortum, S., & Lerner, J. (1999). What is behind the recent surge in patenting? *Research Policy, 28*, 1–22.

Lee, C., Lee, K., & Pennings, J. (2001). Internal capabilities, external networks, and performance: A study on technology-based ventures. *Strategic Management Journal, 22*, 615–640.

Leleux, B., & Surlemont, B. (2003). Public versus private venture capital: Seeding or crowding out? A pan-European analysis. *Journal of Business Venturing, 18*, 81–104.

Lerner, J. (1999). The government as venture capitalist: The long-run effects of the SBIR program. *Journal of Business, 72*, 285–318.

Link, A. N., & Scott, J. T. (2010). Government as entrepreneur: Evaluating the commercialization success of SBIR projects. *Research Policy, 39*(5), 589–601.

Link, A. N., & Scott, J. T. (2012). Employment growth from the small business innovation research program. *Small Business Economics, 39*, 265–287.

Link, A. N., & Scott, J. T. (2013). Public R&D subsidies, outside private support, and employment growth. *Economics of Innovation and New Technology, 22*(6), 537–550.

Lissoni, F. (2012). Academic patenting in Europe: An overview of recent research and new perspectives. *World Patent Information, 34*(3), 197–205.

Lissoni F., Pezzoni, M., Potì, B., & Romagnosi, S. (2013). University autonomy, IP legislation and academic patenting: Italy, 1996–2006. *Industry and Innovation, 20*(5).

Lissoni, F., Llerena, P., McKelvey, M., & Sanditov, B. (2008). Academic patenting in Europe: New evidence from the KEINS database. *Research Evaluation, 17*(2), 87–102.

Lockett, A., Murray, G., & Wright, M. (2002). Do UK venture capitalists still have a bias against investment in new technology firms? *Research Policy, 31*, 1009–1030.

Lotta, V. (2003). *Public provision of business support services in Finland.* ETLA Discussion Papers, The Research Institute of the Finnish Economy (ETLA), No. 850, http://hdl.handle.net/10419/63769

Macdonald, S. (2009). *Seducing the goose. Patenting by UK Universities*. Sheffield: University of Sheffield.

Maia, C., & Cara, J. (2013). The role of a proof of concept center in a university ecosystem: An exploratory study. *Journal of Technology Transfer, 38*(5), 641–650.

Mansfield, E., & Lee, J.-Y. (1996). The modern university: Contributor to industrial innovation andrecipient of industrial R&D support. *Research Policy, 25*(7), 1047–1058.

Meyer, M. (2003). Academic patents as an indicator of useful research? A new approach to measure academic inventiveness. *Research Evaluation, 12*, 17–27.

Meyer, M. S., & Tang, P. (2007). Exploring the "value" of academic patents: IP management practices in UK universities and their implications for third-stream indicators. *Scientometrics, 70*, 415–440.

Moray, N., & Clarysse, B. (2005). Institutional change and resource endowments to science based entrepreneurial firms. *Research Policy, 34*(7), 1010–1027.

Mowery, D. C., Nelson, R. R., Sampat, B. N., & Ziedonis, A. A. (2001). The growth of patenting and licensing by U.S. universities: An assessment of the effects of the Bayh–Dole act of 1980. *Research Policy, 30*, 99–119.

Mowery, D. C., & Sampat, B. N. (2005). The Bayh–Dole Act of 1980 and university–industry technology transfer: A model for other OECD governments. *Journal of Technology Transfer, 30*, 115–127.

Munari, F., & Toschi, L. (2011). Do venture capitalists have a bias against investment in academic spin-offs? Evidence from the micro- and nanotechnology sector in the UK. *Industrial and Corporate Change, 20*(2), 397–432.

Munari, F., Pasquini, M., Toschi, L. (2015). From the lab to the stock-market? The characteristics and impact of university–oriented seed funds in Europe. *Journal of Technology Transfer,* forthcoming.

Munari, F., Toschi, L. (2015). Assessing the impact of public venture capital programmes in the United Kingdom: Do regional characteristics matter? *Journal of Business Venturing*, *30*(2), 205–226.

Mustar, P. (2002). Public support for the spin-off companies from higher education and research institutions. In *Proceedings of the strata consolidated workshop*.

Mustar, P., & Wright, M. (2010). Convergence or path dependency in policies to foster the creation of university spin-off firms? A comparison of France and the United Kingdom. *Journal of Technology Transfer, 35*, 42–65.

Phan, P. H., Siegel, D. S., & Wright, M. (2005). Science parks and incubators: Observations, synthesis and future research. *Journal of Business Venturing, 20*, 165–182.

Ranga, L. M., Debackere, K., & von Tunzelmann, N. (2003). Entrepreneurial universities and the dynamics of academic knowledge production: A case study of basic vs. applied research in Belgium. *Scientometrics, 58*, 301–320.

Rasmussen, E. (2008). Government instruments to support the commercialization of university research: Lessons from Canada. *Technovation, 28*, 506–517.

Rasmussen, E., & Borch, O. J. (2006). *The university and the spin-off process-A dynamic capability approach.*

Rasmussen, E., & Rice, M. P. (2012). A framework for government support mechanisms aimed at enhancing university technology transfer: The Norwegian case. *International Journal of Technology Transfer and Commercialisation 11*(½).

Rasmussen, E., & Sorheim, R. (2012). How governments seek to bridge the financing gap for university spin-offs: Proof-of-concept, pre-seed, and seed funding. *Technology Analysis & Strategic Management, 24*(7), 663–678.

Reale, E., & Poti, B. (2009). Italy: Local policy legacy and moving to an "in between" configuration. *University Governance Higher Education Dynamics, 25*, 77–102.

Rogers, E. M. (2002). The nature of technology transfer. *Science Communication, 23*(3), 323–341.

Salmenkaita, J.-P., & Salo, A. (2002). Rationales for government interventions in the commercialization of new technologies. *Technology Analysis & Strategic Management, 14*(2), 183–200.

Saragossi, S., & de la Potterie, B. V. P. (2003). What patent data reveal aboutuniversities: The case of Belgium. *Journal of Technology Transfer, 28*, 47–51.

Scott J. T. (1989). Historical and economic perspectives on the National Cooperative Research Act in cooperative research and development: The industry–university–government relationship. In A. N. Link & G. Tassey. Dordrecht: Kluwer Academic Publishers.

Siegel, D., Westhead, P., & Wright, M. (2003). Assessing the impact of university science parks on research productivity: Exploratory firm-level evidence from the United Kingdom. *International Journal of Industrial Organization, 21*, 1357–1369.

Stankiewicz, R. (1998). Science parks and innovation centers. In H. Etzkowitz, A. Webster, & P. Healey (Eds.), *Capitalizing knowledge-new intersections of industry and academia* (pp. 133–147). New York: State University of New York Press.

Sterzi, V. (2011) *Academic patent value and knowledge transfer in the UK. Does patent ownership matter?* MPRA Paper No. 34955, posted 23. November 2011/10:07. http://mpra.ub.uni-muenchen.de/34955/

Tang, P. (2008). *Exploiting university intellectual property in the UK.* London: Intellectual Property Institute.

Toole, A. A., Czarnitzki, D. (2005). *Biomedical academic entrepreneurship through the SBIR program.* Working Paper 11450 http://www.nber.org/papers/w11450

Uecke, O., Rajendran, L., Schellin, S., & Simons, K. (2010). *Enhancing effectiveness in early stages of technology transfer and entrepreneurship: The case of a new Alzheimer's disease treatment.* Conference paper 18th annual high technology small firms conference.

Valentin, F., & Jensen, R. (2007). Effects on academia-industry collaboration of extending university property rights. *Journal of Technology Transfer, 32*(3), 251–276.

Van der Steen, M., Bekkers, R., BodasFreitas, I., & Gilsing, V. (2008). *Beyond the demand-side perspective of technology transfer policies: An empirical analysis of the Netherlands.* Conference paper for the DIME conference.

Van Looy, B., Debackere, K., & Andries, P. (2003). Policies to stimulate regional capabilities via university–industry collaboration: An analysis and assessment. *R&D Management, 33*, 2.

van Zeebroeck, N., de la Potterie, B. V. P., & Guellec, D. (2008). *Patents and academic research: A state of the art*. CEB Working Paper No. 08/013.
Vohora, A., Wright, M., & Lockett, A. (2004). Critical junctures in the development of university high-tech spinout companies. *Research Policy, 33*(1), 147–175.
von Ledebur, S. (2009). *University-owned patents in West and East Germany and the abolition of the professors' privilege.* Working Papers on Innovation and Space. Marburg University, Papers no. 02-09.
von Ledebur, S., Buenstorf, G., & Hummel, H. (2009). *University patenting in Germany before and after 2002: What role did the professors' privilege play?* Jena Economic Research Papers no. 2009-068.
Wright, M., & Filatotchev, I. (2008). Stimulating academic entrepreneurship and technology transfer: A case study of Kings College London commercialization strategies. In R. P. O'Shea & T. J. Allen (Eds.), *Building technology transfer in research universities: An entrepreneurial approach*. Cambridge: Cambridge University Press.
Wright, M., Lockett, A., Clarysse, B., & Binks, M. (2006). University spin-out companies and venture capital. *Research Policy, 35*(4), 481–501.