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THE EFFECT OF SUPPORT MEASURES ON INVOLVEMENT IN TECHNOLOGY TRANSFER

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INTRODUCTION

The present PhD dissertation is dedicated to the general topic of knowledge transfer from academia to industry and the role of various measures at both institutional and university levels in support of commercialization of university research. Within this major focus, the dissertation represents a collection of three papers, based on the logic of moving from the broader issue of the role of government in supporting transfer of academic research, to a more specific context of academia, then proceeding with the analysis of the factors that affect the commercialization rate of university patents, and concluding with the study on the role of university-level support measures aimed at enhancing participation of a specific group of academic inventors, i.e. female scientists, in knowledge transfer activities.

The rationale for the present research is explained by a wide set of critical issues arising with regard to commercial exploitation of academic research and the role of the external and internal environment in facilitating the transfer of research results from university or public research institute to industry. Although this topic has been extensively covered in the existing literature, there yet remains a variety of open questions which call for further investigation.

The past few decades have been characterized by an ever growing role of a university as an important player in the national innovation system (Baldini, Grimaldi, and Sobrero, 2006). As such, efficient transfer of research results from academia to industry has become a strategic issue to manage. For university administration, this comes as a consequence of the increased reliance on the funding sources other than the public research funding, while the government authorities have come to see universities as a policy tool for economic development (Geuna and Muscio, 2009).

From a historical perspective, a re-assessment of the role of universities and public research institutes started during the late 1970s in the U.S. leading to a set of reforms which were crafted to enhance the transfer of research results from academia to industry (Coriat and Orsi, 2002). As a result of these specific policy measures and such environmental constraints as decreasing public funding for research (Feller, 1990), universities started to behave in a more proactive way with what regards management of their intellectual property and commercialization of the research carried out by their faculty.

In Europe the environmental forces that led to a situation of an increased involvement of universities in so-called "third-mission" activities, i.e. commercialization of research, were very similar to those registered in the United States in the 1970s. Thus, during the 1990s the budgetary pressures, encountered by European universities as a result of a significant increase in students along with the considerable cuts in the governmental funding, made universities look for additional sources of income and funds for research and operations. Contemporaneously, important changes in the national legislative frameworks were made and a variety of policy instruments in support of academic knowledge transfer and commercialization were put in place, as a consequence of a growing belief of policy makers that universities should have an active role in the innovation process (Baldini et al., 2006: Clarysse et al., 2007). Ever since, an extant stream of academic literature has explored the role of various public reforms and other policy measures in the form of government interventions in addressing the gap between research and actual exploitation of academic knowledge.

The effectiveness of public measures in support of technology transfer and commercialization of university research is among one of the most significant issues on the agenda of the practicing authorities in most countries. With that, although there exists a wealth of academic studies analyzing different policy measures and initiatives implemented by national governments in support of knowledge transfer from academia to industry, no efforts have been done for the systematization of the existing research. With that, this lack of academic attention results to be a significant shortcoming, since there is no solid theoretical foundation for analyzing the role of government in facilitating commercialization of academic research, as well as for the advised and well-crafted decisions regarding the design and implementation of such measures. The first paper included in the present PhD dissertation aims to address this gap by developing a taxonomy of literature, based on a comprehensive review of the existing body of research on government measures in support of knowledge transfer from academia to industry. In particular, a two-dimensional approach is proposed, according to which all the identified relevant studies are classified. The results of the review reveal that there is a considerable gap in the analysis of the impact and relative effectiveness of the public policy measures, especially in what regards the measures aimed at building knowledge and expertise among academic faculty and technology transfer agents.

Another critical issue pertaining to the academic knowledge transfer is related to the determinants of patent commercial exploitation. There has been quite an extant array of academic studies which consider the underlying factors of the successful commercialization of corporate patented inventions; however, to the best of our knowledge, no research so far has explicitly addressed the issue of underutilization of patented inventions generated at universities, and the determinants of the nonuse of such patents. The second paper, presented as a part of the dissertation, addresses this important shortcoming by focusing on the role of interorganizational collaborations during the inventive process and their effect on the likelihood of a patent, resulting from such research, to remain unused. In particular, in my research I focus on the utilization of academic patents, i.e. patents with at least one university-affiliated inventor on the patent team. There has been an extant attention dedicated to exploring the determinants of patent nonuse, but, as underlined above, the focus has been primarily on the industry patents, while very limited attention has been given to the determinants of nonuse of academic patents. With the respective paper included in the dissertation, I aim to cover this gap by putting forward and testing the hypotheses on the effect of external knowledge received from collaborations with various actors during the invention process. The novelty of this piece of research lies in the fact that it looks at the role of R&D collaborations with external parties in commercial success of a resulting patented invention with regard to university patents, which, to the best of my knowledge, has not been done in the previous research.

Besides the main findings of the paper regarding the hypotheses proposed, the additional contribution of this line of research, included in the dissertation, lies in the fact that I distinguish between different types of nonuse, namely, nonuse out of blocking consideration, and nonuse with the intention to exploit a patent in the future. As the recent literature demonstrates (e.g. Giuri et al., 2013; Torrisi, 2013), these are important dimensions to consider and to distinguish when talking about the commercial exploitation of patents, both corporate and academic, since patent nonuse may be directly related to the strategic management of IP assets. I apply the concept of "strategic nonuse" to a particular group of participants to the innovation process, i.e. universities. The results of the study, in fact, suggest that there might be a more strategic dimension to universities' behaviour with regard to their patent portfolios as it has been traditionally perceived.

Finally, moving from a more general and theoretic issue of government support for commercialization, as well as the determinants of nonuse at the level of a single patent, I turn to a specific institutional case, i.e. Italy, to investigate yet another issue with regard to academic knowledge transfer that has been currently receiving a growing attention from both the scholars and practitioners, but which still remains a highly underexplored area of academic research, that is female participation in patenting. This issue happens to be of considerable relevance since patenting is a precursor to commercialization, and it is through commercialization that the inventions are brought to the market and, thus, an innovation occurs. Since women currently represent almost half of the scientific workforce in most developed countries, the issue of broader participation of female scientists at all stages of the innovation process is of high importance for the sustainable development of national innovation systems. In a dedicated paper, I turn to this current issue and explore the role of university in closing the gender gap in female academic patenting. More specifically, I investigate the impact of a technology transfer office, as well as the internal IPR regulations on the likelihood of having at least one female academic inventor on the patent team. I also look at the more general effect of institutional ownership on female participation, arguing that there will be a higher probability to find “female” patents among university-owned as compared to university-invented patents. The unique contribution of this paper regards an added value created at two levels: organizational (university) and country level. Being placed in a national context, the paper provides policy implications for both universities and national governments in the field of gender equality in science and academia respectively, resulting to be of particular relevance in the situation of an ever increasing awareness and sharp concern about the underlying factors behind the gender gap in scientific and, more recently, in the commercial involvement of academic scientists (Frietsch et al., 2009; Technopolis, 2008). With the focus for scientific research shifting from basic to applied research and innovation, and with the patents granted becoming one of the primary indicators of research excellence (Rosser, 2009), the failure to introduce effective and relevant measures and instruments aimed at addressing the gender gap in patenting will result in reduced competitiveness of the national economies, as well as in decreased innovative growth in the long term period.

Based on all of the above said, the overall contribution of the present dissertation work refers to presenting an in-depth and comprehensive analysis of the main critical issues that currently exist with regard to commercial exploitation of academic research, while providing evidence on the role of previously underexplored areas (e.g. strategic use of academic patents; female academic patenting) in a general debate on the ways to successful knowledge transfer from academia to industry.

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Anna Kochenkova

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

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

Abstract

Although there is a wealth of academic studies analyzing different policy measures and initiatives implemented by national governments in support of knowledge transfer from academia to industry, no efforts for the systematization of disparate lines of research have been done so far. Until now the analysis of policy measures and initiatives has been based mainly on benchmarking and experimenting, rather than on solid and validated conceptual frameworks. Apart from the fact that the number of government support programs and the resources invested in these has increased radically, there remains much work in integrating disparate practices into conceptual models that can lead to improved impact of these programs and improved return on investment of resources. With the aim of addressing this gap, we develop a conceptual framework for the analysis of the role of government in facilitating commercialization of academic research and university-industry collaboration. We suggest that this framework is useful in guiding future research in this important, yet under-explored field. Our review reveals a major gap in the academic literature on the effectiveness of the public policy measures, as contrasted to the mere analysis of the design of such policies.

We conclude by highlighting critical issues identified, opportunities for methodological improvement and recommendations for policy intervention.

Keywords: Public policy measures, Government support of technology transfer, Commercialization of university-research

1. Introduction

Over the last years there has been an ever growing attention from national governments and regional authorities towards the development of technology transfer activities from universities to the industry. This particular interest may be explained by the increased emphasis attributed to "third mission" activities of universities for the sustained and continuous development of national and regional economic systems (Etzkowitz et al., 2000; Gulbrandsen and Slipersæter, 2007; Rasmussen and Borch, 2006). Through making available to the market new products, processes and services, the commercialisation of research outcomes may contribute to solving social, cultural or environmental challenges, along with being an important mechanism for industry development (Rasmussen and Rice, 2012). One of the reasons for this surge of attention lies also within the fact that, under the conditions of general tendency towards decreasing government funding for research (Geuna, 1998; Calderini et al., 2003), the commercialization of university knowledge has become a notable additional source of income for universities (Baldini et al., 2010; Etzkowitz et al., 2000). Thus, universities have regarded technology transfer activities as an important means to "defend" universities' scientific position by creating new mechanisms for funding research activities, such as royalty streams on licensed technologies, revenues from the sale of shares in academic spinoffs, from research contracts or from consulting services with companies. An additional indirect payoff of technology transfer activities rests on the possibility to strengthen the general reputation of the university by attracting the brightest students and researchers (Baldini et al., 2010).

This new role of universities with respect to the commercialization of research results has been embedded as an integral element in the government innovation policy across countries (Mansfield and Lee, 1996). In spite of the fact that the number of government support programs and the resources invested in these has increased radically, there remains much work in integrating disparate practices into conceptual models that can lead to improved impact of these programs and improved return on investment of resources. Indeed, different countries, as well as the single universities, vary considerably in their approaches to facilitate university knowledge transfer (Geuna and Muscio, 2009). However, until now the analysis of policy measures and initiatives has been based mainly on benchmarking and experimenting, rather than on solid and validated conceptual frameworks (Feldman et al., 2002).

Following this general trend, there has been a growing amount of academic studies in the fields of economics and management of innovation analyzing the design and impact of public policy measures aimed at increasing technology transfer activities and university-industry links, especially through formal mechanisms such as patenting, licensing and the creation of spin-offs. However, most existing studies are focused on the experience of a single country, or on the investigation of a limited number of public support measures (e.g., Goldfarb and Henrekson, 2003; Mustar and Wright, 2010; Rasmussen, 2008; Rasmussen and Rice, 2012). This lack of systematic account of the lessons learnt makes it difficult to produce clear and evidence-based indications for policy-making. This raises a need for a comprehensive study based on a systematization of the scientific literature on public policy measures supporting technology transfer activities. With the present research we aim to systemize the existing literature on the public policy measures in support of knowledge and technology transfer across Europe, US, and other selected countries. We do so by providing an updated, comprehensive overview of economic and management studies in the field, as well as highlighting the main results obtained, the major limitations and some under-addressed opportunities for research. It also aims to clarify salient issues for policy makers and thereby to further inform evidence-based policies. As its main contribution, the present study offers a conceptual framework for the analysis of the role of government in facilitating commercialization of academic research and university-industry collaboration in general.

The remainder of the study is organized as follows. Section 2 describes the methodology which has been utilized for the purpose of the present research. In Section 3, rationales for government intervention in the process of commercialization of university knowledge are discussed. Section 4 presents a conceptual framework we use to review the existing academic research, while Section 5 provides a detailed account of the main public policy measures in support of knowledge transfer which have been addressed by the existing literature. Finally, the discussion of identified research gaps and critical issues, along with the policy implications and recommendations for future research, are finally presented in Section 6.

2. Methodology of the review

With the scope of developing a comprehensive overview of the academic research on the public measures in support of university knowledge transfer, we applied the following exploration process. We started by using comprehensive electronic reference retrieval services like Scopus, Google Scholar and Proquest to run keyword queries to identify all scholarly articles published in refereed journals, as well as the working papers and book chapters, related to the topic of public policy measures to enhance technology transfer and university-industry collaborations. We used the following keywords (and combinations of keywords) in order to retrieve articles and working papers relevant for our analysis: “technology/knowledge transfer”, “university-industry collaboration”, “public support mechanisms/measures”, “government support”, “venture capital”, “university seed funds”, “academic start-ups/spin-offs”, “university incubator”, “science park”. The initial sample that we obtained from this search, based on the above keywords, included over 80 studies. We then scanned each of the identified papers to select only those which explicitly refer to public support mechanisms aimed at enhancing university knowledge transfer activities (and not, in more general terms, innovation or entrepreneurship at large). Moreover, we decided to include in the analysis only those studies which investigated in-depth and addressed specifically single policy measures or a wide set of measures oriented to technology transfer, and decided to exclude those studies which only marginally mentioned or discussed policy measures, having a different ultimate aim. The final sample thus includes 46 studies which we analyzed in detail creating a database with the following data: (1) author name(s), article title, and year published, (2) research question(s), (3) public policy measure(s) considered; (4) focus of the paper (description of the design/characteristics of the measure or the impact thereof); (5) main findings and conclusions. The review provided below is largely based on the data retrieved from the papers included in this final sample. Annex 1 reports the detailed list of the studies included in the review.

3. Rationale for government intervention in support of technology transfer activities

The historical background of the phenomenon demonstrates that the increased levels of technology transfer registered across countries in the last few decades have been largely due to the implementation of dedicated public policy measures to foster technology transfer activities at the universities (Feldman et al., 2002). In order to pursue such objectives, the government intervened in the form of enforcement of legislative acts and other regulations related to IP ownership and exploitation of research results (Baldini, 2006; Della Malva et al., 2008; Geuna and Rossi, 2011; Lissoni et al., 2012), as well as establishment of publicly funded structures and programs to support universities in their transition to commercialization activities (Rasmussen, 2008; Rasmussen and Rice, 2012; Wright et al., 2006). According to the current economic literature, the main motivations to justify the public intervention to support universities' "third mission" activities relate to the existence of a set of barriers in the form of market inefficiencies (e.g. Salmenkaita and Salo, 2002).

The arguably most significant hurdle among the market inefficiencies refers to the so-called *funding gap*, i.e. lack of private funding sources to support technology transfer activities and academic spin-offs, also among more "advanced" and risk-oriented investors such as venture capital firms or business angels (Lockett and Wright, 2008; Munari and Toschi, 2011; Salmenkaita and Salo, 2002). As a general rule, university-generated inventions tend to be embryonic in nature and are often at the frontier of scientific advancements (Colyvas et al., 2002; Jensen and Thursby, 2001), thus involving considerable risks associated with their subsequent validation, industrialization and commercialisation.

In the specific case of academic spin-offs, the low availability of private investments also among independent venture capital (VC) firms is linked to elevated transaction costs, significant asymmetric information between early stage ventures and potential external investors, as well as high risks pertaining to the uncertainty of project outcomes (Munari and Toschi, 2011; Murray, 2007; Murray et al., 1998). In addition to that, the major part of academic start-ups is generally not "investor ready" since such start-ups emerge in a non-commercial and non-competitive environment as that of a university or research institution (Rasmussen and Sorheim, 2012). Private VC firms may suffer from a so-called *anticipatory myopia* (Salmenkaita and Salo, 2002) since they tend to focus on "hot" technologies and bypass other projects which may have a potential socially beneficial impact but may seem much less "attractive" in terms of short-term gains.

Finally, the problem related to the availability of initial VC capital for academic spin-offs may be due to a general underdevelopment of the venture capital infrastructure at the country level (Rasmussen and Sorheim, 2012).

Along with the structural rigidities and market failure to provide enough capital at the early stages of commercialization of academic knowledge, Salmenkaita and Salo (2002) talk about another rationale for the government intervention, i.e. *systemic failure*. In particular, it relates to the fact that since the effectiveness of the innovation system depends on the interactions between various players (e.g. companies, government laboratories, universities), the differences in the priorities, goals and objectives of various participants to the innovation process may endanger the long-term performance of the innovation system leading to a systemic failure. The government intervention can mitigate such systemic failures in the commercialization of new technologies by creating incentives that facilitate interactions, collaborations, knowledge and technology exchange between organizations at different stages of innovation process (Salmenkaita and Salo, 2002). Among the examples of such government strategies to mitigate the systemic failure is the introduction of the technology programs aimed at promoting collaborative R&D projects between industry and academia.

Just like there are differences in the goals and priorities of various actors, there as well exist differences in expertise, culture, and language between academics and potential users of the technology (Rogers, 2002) which may create *a communication gap* that arises during the phases of technology transfer and, thus, provides another rationale for government intervention. The low level of comprehension of the academic language and principles by industry players, as well as a generally diffused lack of awareness and understanding of business culture and the requirements of the commercialisation process by the academic scientists (Stankiewicz, 1994; Rasmussen and Rice, 2012) hinder the knowledge and technology flow from university to industry, and, thus, requires intervention from the third party – the government – to bridge the communication gap between academia and industry by providing dedicated facilities and consulting assistance to support different actors throughout the knowledge and technology transfer process (Feldman et al., 2002).

A final problem, that has received coverage in the academic literature, relates to the existence of *a knowledge gap*, related to the fact that academic researchers and entrepreneurs supposedly lack managerial skills and competences to develop their technologies and start-ups up to a point where it is possible to negotiate successfully with industrial partners or external investors (Rasmussen and Rice, 2012; Franklin et al., 2001). Such knowledge gap may also be extended to the case of the staff engaged in university technology transfer offices (TTOs) or incubators, especially for newly established ones, who may not necessarily have the adequate educational and professional background to deal with the members of the industrial or financial world. This provides further support for the need to implement public policies designed with the specific goal of building competence inside universities by educating the university staff on the commercialization and technology transfer aspects.

The abovementioned barriers and gaps between the generators of new knowledge – universities - and the intended adopters of such knowledge – industry, public administration and society at large - have been addressed by the national and regional authorities and policy makers with the aim of enhancing the effectiveness of the commercialization and knowledge transfer from academia, and, thus, increasing the economic and social impact at large (Feldman et al., 2002). In the following section, we provide an extensive overview of the academic studies that focus explicitly on such public policy measures, and, based on this review, we suggest a conceptual framework for the analysis of the multifaceted role of government in facilitating commercialization of academic knowledge.

4. The conceptual framework

For the purposes of the present research, we have identified two conceptual dimensions for classifying the articles and working papers for further analysis. In our view, this framework results useful in interpreting the main findings and identifying the research gaps and promising research avenues. We do believe that these two dimensions of analyses could provide insightful implications for policy makers to design evidence-based policies in this area. The first analytical dimension we used to classify existing literature relates to the type of policy measure analyzed in the study. Based on the analysis of existing literature, we were able to identify three macro areas of public interventions. The first area includes ***legislative/institutional reforms*** aimed at defining the rules and boundaries to undertake technology transfer activities between universities and the industry in the country. In this first type of general measures, we were able to find articles dealing, for instance, with university IPR reforms, laws on the financial and organizational autonomy of universities, regulations on researchers' status, laws for the establishments of TTOs at universities or other infrastructures in support of technology transfer, and laws to regulate university-industry collaborations. The second macro area comprises ***direct financial support measures*** aimed at facilitating the transfer of technology from universities to the industry. In this area, we found studies analyzing subsidies programs or commercialization grants, proof-of-concept or translational funds, pre-seed and seed funds, funding programs for the establishment of TTOs, incubators or science parks, funding programs to facilitate university-industry collaborations. Lastly, the third set of measures includes ***competence-building measures*** aimed at facilitating the transfer of technology from universities to the industry. In this area, we found studies dealing with public support for the establishment of training programs and competence building programs for both university researchers and entrepreneurs and for TTO staff.

The second conceptual dimension that we used to classify existing literature looks on the *focus* of the articles on either the design of public policy measures in support of technology transfer, or on the ultimate impact of such measures. The former set of articles adopt a more descriptive approach to present the aims and specific features of various policies implemented in different countries. The latter set of studies, on the other hand, tried to assess the effectiveness of such programs using different approaches and performance indicators. Table 1 classifies the studies according to the two dimensions of the analysis.

Table 1 – Conceptual framework of the review and classification of existing academic studies

	FOCUS	
POLICY MEASURE	**DESIGN**	**IMPACT**
LEGISLATIVE/INSTITUTIONAL MEASURES		
IPR legislation	Baldini (2006); Baldini et al. (2012); Damsgaard and Thurnsby (2012); Gallochat (2003); Geuna and Rossi (2011); Goldfarb and Henrekson (2003); Jacob et al. (2003); Mowery and Sampat (2005); Ranga et al. (2003); Saragossi and van Pottelsberghe de la Potterie (2003)	Baldini et al. (2006); Damsgaard and Thursby, 2012); Della Malva et al. (2008); Huelsbeck and Lehmann (2006); Mowery and Sampat (2005); Valentin and Jensen (2007); Von Lebedur et al. (2009); Von Lebendur (2009);
Other types of legislation and regulations	Baldini et al. (2006; 2010); Gallochat (2003); Goldfarb and Henrekson (2003); Jacob et al. (2003); Lissoni et al. (2012); Mustar and Wright (2010);	Della Malva et al. (2008); Lissoni et al. (2012); Mustar and Wright (2010);
FINANCIAL SUPPORT MEASURES	Abetti (2004); Bigliardi et al. (2006); Clarysse et al. (2007); Della Malva et al. (2008); Eickelpasch and Fritsch (2005); Goldfarb and Henrekson (2003); Hulsink et al. (2008); Huggins (2006); Lotta (2003); Mustar (2002); Ramsussen (2008); Rasmussen and Rice (2012); Rasmussen and Sornheim (2012); Uecke et al. (2010); Van der Steen et al. (2008); Wright et al. (2006)	Borlaug et al., (2009); Rasmussen and Rice (2012)
COMPETENCE DEVELOPMENT MEASURES	Mustar (2002); Mustar and Wright (2010), Rasmussen (2008)	

From the Table 1 one can immediately see that there are certain areas of government intervention and support which have received abundant attention from the academic researchers over the last two decades, while there are also areas which have lacked such focus and which, thus, represent major gaps in terms of existing contributions. It appears clear that there has been a disproportionately larger number of papers focusing on the design of university intellectual property right (IPR) reforms in the various countries, following the path-breaking experience of the Bay-Dole Act in the United States (e.g. Mowery and Sampat, 2005; Goldfarb and Henrekson,2003; Baldini et al., 2006), while on the other hand very few papers have studied other types of legislative and institutional reforms, other than those on IPRs (e.g. Jacob et al., 2003; Lissoni et al., 2012; Mustar and Wright, 2010). In a similar vein, in the case of studies investigating public financial measures in support of technology transfer, it clearly emerges that the major emphasis has been placed on the description of different types of financial measures (Della Malva et al., 2008; Mustar, 2002; Rasmussen, 2008; Rasmussen and Sorheim, 2012; Wright et al., 2006), whereas there is a significant lack of research on evaluating the impact of such support measures (Borlaug et al., 2009); Rasmussen and Rice, 2012). Finally, there emerges a considerable gap in the scientific research regarding the third group of public policy measures, namely the measures aimed at funding competence-building initiatives and training programs (e.g. Mustar and Wright, 2002; Rasmussen, 2008). Although our previous discussion has pointed out that the so-called knowledge gap represents a serious barrier for the success of technology transfer activities, the existing literature has almost completely neglected this area of government intervention and support.

In the following section we provide a more detailed discussion of the existing studies addressing the various types of public policy measures and of their findings, in order to identify at a more fine-grained level unaddressed questions and opportunities for future research.

5. Findings

Existing evidence on public policy measures in support of technology transfer

In this section we present the findings from the systematic review performed. Each of the following subsections provides a detailed account of a distinct set of public policy measures, according to the classification specified in the previous section.

5.1. Legislative/institutional measures

The first set of studies that we have identified address the government legislative reforms which were introduced in different countries to promote technology transfer. These studies, in general, provide an overview of the legislative reforms pertaining to the ownership of the patent rights, as well as of other regulations targeted at fostering commercialization of academic inventions and university-industry collaboration.

There is a widely-accepted belief that the catalyst to the commercialization of university research and academia-industry collaboration has been the changes in the legislation enforced by the governments in various nations (Geuna and Rossi, 2011). Thus, two types of policy initiatives are considered to have accelerated the rate of knowledge and technology transfer from universities to industry: dedicated regulations designed to stimulate research joint ventures between universities and firms (e.g. the Cooperative Research Act in the US), and changes in the intellectual property ownership regime in favor of universities (e.g., enactment of the Bayh-Dole Act of 1980 in the U.S. and Bayh-Dole Act-like legislations in European countries) (Scott, 1989; Crow and Bozeman, 1998).

As previously mentioned, most of the attention in the literature has been devoted to this latter type of reforms related to the ownership of university IPRs. The most notable example of this type of policy reforms is the 1980 Bayh–Dole Act in the United States that allowed universities to retain IPR on the inventions resulting from federally funded research. The Bayh-Dole Act was followed by a series of similar reforms in Europe and other countries, and originated a rich and diversified stream of economic literature on actual consequences in terms of patenting behavior and commercialization outcomes.

In spite of the lack of agreement on the real effects of the Bayh–Dole Act on academic patenting and other forms of technology transfer activities (some empirical studies suggest that the increase in patenting by US universities in the 1990s was due only in part to this piece of legislation (Mowery et al., 2001; Rafferty, 2008), most European countries, being convinced of a strong causal link between these phenomena (OECD, 2003), have implemented changes to their national regulations in IP (Geuna and Rossi, 2011). Several studies have thus described the implementation of this type of reforms in various countries, such as UK (Mcdonald, 2009; Meyer and Tang 2007; Tang, 2008), Italy (Balconi et al., 2003; Baldini et al., 2006), Germany (Von Lebedur et al., 2009; von Lebedur, 2009; Czarnitzky et al., 2011), Spain (Cesaroni and Piccaluga, 2003; Azagra-Caro et al., 2006; Azagra-Caro, 2010), Denmark (Baldini, 2006), Belgium (Ranga et al. 2003; Saragossi and van Pottelsberghe de la Potterie, 2003), France (Azagra-Caro et al., 2006; Carayol and Matt, 2004; Cesaroni and Piccaluga, 2003; Della Malva et al., 2008; Lissoni et al., 2008), and Sweden (Jacob et al., 2003; Damsgaard and Thurnsby, 2012).

Although most studies provide evidence that the Bayh-Dole Act in the US and similar regulations in other countries gave universities greater incentives to commercialize their inventions, some researchers have expressed doubt as to whether this sort of regulation has had a major influence in fostering technology transfer (e.g. Mowery et al., 2001; Kenney and Patton, 2009). As some studies suggest, several leading American universities, such as the University of California and the Stanford University, had already become increasingly active in patenting before the Act, and many European countries, in which a similar phenomenon has been observed, did not have Bayh-Dole Act-like regulations in force at that time (Mowery et al., 2001).

Geuna and Rossi (2011), in their comprehensive study on university IPR ownership regulations in Europe, argue as well that the phenomenon of the general increase in the number of university-owned patents across Europe which can be often observed after the reforms in many studies cannot be entirely ascribed to changes in university IPR legislations, since the shift to university-ownership system has been accompanied by other important changes which could have triggered an increase in university commercializing activities. Thus, in the US the Bayh-Dole legislation was accompanied by other legislative acts (e.g. University and Small Business Patent Procedures Act) which enabled federal government to arrange for the licensing of patents not exploited by academic administrations (march-in right) (Geuna and Rossi, 2011). The subsequent measures included US legislation extending the scope and duration of patent protection (Feldman and Stewart, 2006, Kortum and Lerner, 1999; Jaffe, 2000), along with the progressive removal of the obstacles to commercial exploitation of the results of research conducted in public laboratories (Geuna and Rossi, 2011).

The empirical evidence provided by the studies, which analyze the consequences of the new reforms in different countries, shows that in general the amount of university-invented patents increased (Baldini, 2006; Baldini et al., 2006; Della Malva et al., 2008; Tang, 2008), while the effect on the amount of university-owned patents results to be controversial. For instance, as the studies on Germany by von Lebendur (2009) and von Lebendur et al. (2009) show, there has been registered a consistent increase of university-owned patents. However, there still exist very few studies that focus on the impact of the above reforms on the value of university patents (e.g., Sterzi, 2011; Czarnitzki et al., 2011), with only a number of most recent studies looking at their effect on the exploitation rates of academic patents (e.g.. Callaert et al., 2013; Crespi et al., 2010; Lissoni et al., 2013, etc.). All this points to a significant gap in the scholar assessment of the quality of the reforms in the sphere of IPR ownership both at country and multi-country level, which will have to be addresses in the future research.

A much more limited set of studies have addressed a different group of legislative reforms, namely those regulating *the researcher's status*. For instance, Gallochat (2003), Mustar and Wright (2010), and Clarysse et al. (2007) provide the example of France, where until 1999 academic researchers were precluded from creating their own company for the sake of developing and exploiting their research results while keeping their status of civil servants (Gallochat, 2003). It was only in July 1999 that a newly introduced Law on Innovation and Research to Promote the Creation of Innovative Technology Companies cancelled this obstacle and in this way fostered the creation of a new status for researchers and academics.

According to this Law, the academics were granted the right to participate as a founder, consultant, or a manager in a new company and to take equity. The Law also provided the possibility for a researcher to contribute to the capital of a company that is developing his/her research work while holding up to 15% of the capital of the company (Gallochat, 2003). As one can see, the above legislative measure has provided quite an extant range of opportunities for academic scientists to engage in commercialization of their research work. The authors

A further legislative measure, introduced by the French Government in 2002, is discussed by Clarysse et al. (2007). Specifically, it was implemented in the form of a decree which was to regulate the income an academic can get out of an IP on a personal basis (which may amount to 50%). As it is reported in the study,

Geuna and Nesta (2006) in their research highlight that in a number of EU countries researchers were granted as well the right to receive a portion of the royalties derived from their patented discoveries, even in cases when the IPRs belong to the institution in which the discovery was developed. Clarysse et al. (2007) and Debackere and Veugelers (2005) provide evidence for Belgium, showing in particular that, along with the introduction of the legislative change in 1996, according to which universities received a legal mission to commercialize research results, other changes in the national legislative framework included the provisions which made it easier and less ambiguous for academics to start-up companies. However, these studies do not provide any evaluation of the impact of this type of measures. The effectiveness of the legislation on the researcher's status in France is considered in the study by Mustar and Wright (2010). The authors find no evidence that the creation of new academic ventures results to be more numerous after the implementation of the 1999 Law as compared to the situation in the past.

Other forms of legislative measures analyzed in the academic literature to some extent include national laws which encouraged and regulated the *creation and status of university technology transfer offices (TTOs*). For instance, Goldfarb and Henrekson (2003) report a dramatic increase in the number of TTOs across universities in the US, arguing that the creation of TTOs was incentivized by the Bayh-Dole Act itself, since once universities were granted the property rights, they were motivated to put in place efficient internal mechanisms to solicit disclosures by the faculty and thus maximize economic returns from technology transfer.

With regard to the European evidence, Della Malva et al. (2008) look at the example of France, where the Innovation Act of 1999 introduced the possibility for both universities and public research organizations to create internal TTOs, with the possibility to staff them with external personnel and to run them according to business-like budgetary and accounting rules. The authors produce evidence that the establishment of a TTO results to have a strong and significant impact on the decision of universities to retain IPRs over their scientists' discoveries.

This measure encourages in particular, the creation of high technology companies by research staff and students.

In a similar vein, national governments have introduced legal provisions directed at fostering the creation of other internal infrastructure facilities, such as university incubators, innovation agencies or science parks, aimed at boosting technology transfer and innovation. For example, in France the creation of university incubators was fostered by the already mentioned Law on Innovation and Research to Promote the Creation of Innovative Technology Companies. This provision is discussed in the studies by Gallochat (2003) and Mustar and Wright (2010). The Law granted universities and research institutions with the possibility to create incubators for the purpose of providing premises, equipment and other resources to their faculty members who wish to found a new company, or to the already existing young companies (Gallochat, 2003). As for the effectiveness of such legislative measure, the study by Gallochat (2003) reports a positive trend in the number of newly created companies at universities. However, the main limitation of the study is that it was performed almost right after the implementation of the measure, when temporal data were not available. In contrast, a much more recent study by Mustar and Wright (2010) highlight that there has been a small and decreasing number of academic spinoffs in France. The authors argue that this may be due to the misinterpretation of the purpose and, thus, false expectations with regard to this type of public policy measures. More specifically, they point out that such government policies are to define the legal environment and establish a general framework for commercialization of university research, rather than to be used to solve any specific problem. This happens because of the expectations of public policy makers are based on the trajectory which proves to be far from reality, that is a linear path of an invention from the academic lab to the market. This rigidity in the expectations and, thus, in the range of available configurations, often limits the development of academic startups. As the authors underline, the suboptimal impact of the legal policy measures can be mostly explained by the underestimation of the time scales from the funding authorities, the underestimation of the learning process of newly established structures and their management staff, as well as of the difficulties in changing culture and attitude in such old-established organizations, as those of universities (Mustar and Wright, 2010).

A rather extant stream of academic literature exists on legislative measures directed at establishing *university autonomy* which implies less reliance on public funding and, as a consequence, the freedom and the need of getting additional resources from industry, by engaging in technology transfer and commercialization activities (Baldini et al., 2006, 2012; Lissoni et al., 2013; Lissoni, 2012; Reali and Poti, 2009). The design, implementation and effectiveness of this type of legislative reforms, which were widely implemented in Italy, are well discussed in the papers by Baldini et al. (2006; 2012) and Lissoni (2012). The enforcement of Laws n. 400/1988 (i.e. self-regulation principle) and n. 168/1989 (i.e. establishment for the first time of a Ministry for university and research separated from that for education) marked the beginning of the reform towards higher autonomy among Italian universities. Thus, from the early 1990's, academic institutions were granted greater autonomy by being allowed to manage their budgets, to design their teaching programs, and to introduce statutes and regulations for managing organizational and scientific activities, locally. As a result of the introduction of autonomy-accountability principles for university governance (Reale and Poti, 2009), Italian STEM universities established explicit internal IPR regulations, and created internal mechanisms in support of commercialization and technology transfer (Baldini et al., 2012). Regarding the relative effectiveness of this group of legislative acts, in their most recent study Lissoni et al. (2013) report a positive impact of granting of autonomy to universities on the domestic patenting by Italian academic inventors. Besides, as the authors highlight, this public measure has increased the amount of university-owned patents, since the granted autonomy has fostered the universities to be more pro-active in managing the research results of their employees by retaining a share of IP over their staff's inventions with the scope of the subsequent commercialization. As it can be seen, the effect of this type of measure in Italy has brought about positive results through empowering universities to be more accountable and, thus, more active in technology transfer.

However, the issue that arises is whether the institutional ownership – as the main outcome of the reform – has resulted in successful commercialization of university-owned patents. There has been a quite limited amount of academic papers dedicated to this issue. The most recent study by Giuri, Munari and Pasquini (2013) analyzes whether and how the type of ownership affects the probability of commercialization, and if the characteristics of national university IPR regimes correlate with it. The authors find that university ownership has a positive effect on the likelihood of patents being commercialized through licensing, while no such evidence is found for the spin-off creation, which may mean, as the authors argue, that spinoff formation is the more preferable commercialization route in case of the individual ownership. These findings may be interpreted in a way that the policy measures promoting university's autonomy are not enough per se, and that they should be accompanied by other types of measures discussed above and aimed at creating favorable conditions for being able to commercialize academic research through various channels.

Finally, certain legislative acts and regulations aimed at enhancing innovation and technology transfer may provide for specific measures to *promote university-industry collaboration*. The most widely used measure in this respect is tax-deduction schemes, which vary from country to country in what regards the specific characteristics of the measure, but the rationale for this type of measures remains the same: to provide incentives for the industry to engage in collaborative research and commercialization projects with the academia. Among the most well-known and well-discussed legislative measures to foster university-industry collaboration is the Cooperative Research Act in the United States, which several authors (e.g., Scott, 1989; Crow and Bozeman, 1998) report to have had a positive effect on the amount of links between industry and academia.

As a general rule, regulation changes, described above, were accompanied by the development and implementation of funding mechanisms aimed at fostering commercialization of academic research and supporting the creation of technology transfer offices and other support infrastructure (e.g. venture capital, incubators). We provide a detailed account of the coverage of this type of public policy measures in the academic literature in the following section.

5.2. Direct financial measures

Another set of studies in the economics and management literature has analyzed policy measures which directly provide financial support to universities and PROs, TTOs or other technology transfer structures, university or PRO spin-offs, research teams or individual researchers in order to facilitate technology transfer activities and results. In this section, we will briefly summarize the findings of such studies, grouping them by type of measure under analysis.

5.2.1. Commercialization grants/subsidies

Besides creating a favorable legislative environment for enhanced commercialization of academic inventions, university-industry collaboration and spin-off formation, national governments and regional authorities around the world have adopted a wide variety of public policy measures aimed at providing finance and other forms of assistance to the universities and research institutions to assist them in moving to commercialization. In addition to this, certain measures have been implemented in order to encourage venture capital and business communities to participate more actively in the technology transfer processes.

First, the literature has investigated a group of publicly funded programs which are aimed at assisting universities in shifting to commercialization and engaging more smoothly in technology transfer and cooperation with the industry (e.g. Clarysse et al., 2007; Ramsussen, 2008; Rasmussen and Rice, 2012; Wright et al., 2006).

Rasmussen (2008) provides a detailed account of the most important initiatives at federal level in Canada. Thus, the author investigates one of such federally-sponsored programs aimed at accelerating the knowledge and technology transfer from the local universities, known as the Intellectual Property Mobilization program (IPM). As highlighted by the author, IPM grants were intended to further strengthen the ability of Canadian universities to manage their IP, attract potential users, and promote the professional development of IP personnel through a network approach (Rasmussen, 2008). One of the distinctive features of this measure is that, in order to foster innovation and experimentation, preferences are given to innovative approaches and collaborative projects. In particular, one type of IPM awards are so-called group awards, which provide funding for groups of institutions to undertake cooperative activities and broaden existing capabilities (e.g. funds are used for administrative costs in support of group meetings and activities, salary of regional technology transfer experts, and travel expenses, etc.) (Rasmussen, 2008).

Borlaug et al. (2009) reports about the FORNY program in Norway which is considered to be the main support mechanism for commercialization of public funded research in the country. It was established during the 1990s and it targets the university TTOs instead of the researchers directly. A particular feature of the program is that, although most of FORNY's budget is channeled through the TTOs, the so-called infrastructure funds could be provided also to institutions other than TTOs to build entrepreneurial culture and raise the awareness of commercialization and academic entrepreneurship among institutions' students and staff . The study by Borlaug et al. (2009) reports that, as a result of the support obtained from the FORNY infrastructure funds, a large number of events have been organized on an annual basis, showing a significant effort of the government to build entrepreneurial culture in academia and to foster technology transfer. According to the paper, it is important to highlight the fact that many of the Norwegian initiatives are partly developed by experimentation and in collaboration with the actors at a local level. Moreover, as the infrastructure became more developed at institutional and regional levels, the need for government intervention was changing.

Rasmussen and Rice (2012) look at the case of Norway as well, underlining that the development of efficient policy initiatives in the country followed a bottom-up approach, through working closely with local-level actors and taking into consideration the current needs at the operational level. As reported in the literature, in other countries some of the public policy measures targeted at fostering technology transfer are characterized by a similar logic of encouraging collaboration between academia and industry players and experimentation by the local actors, in line with the bottom-up approach applied by the national governments (Rasmussen, 2008; Rasmussen and Sorheim, 2012).

An interesting perspective on this type of public measures is developed in the paper by Toole and Czarnitzki (2005) where the authors analyze the U.S. Small Business Innovation research (SBIR) program as a policy action fostering academic entrepreneurship. They find evidence for the "certification hypothesis" proposed by Lerner (1999), according to which the academic start-ups that had completed the SBIR program were more likely to receive follow-on venture capital funding.

In addition to the granting opportunities provided by national governments to the universities and public research institutes described above, some studies address a particular group of commercialization grants that are field-specific. For instance, the dedicated study by Rasmussen (2008) reports that in Canada there exist special public funding programs aimed specifically at the commercialization of health research from universities and research hospitals. The main feature of such programs is that they are, as a rule, developed in cooperation with the end-users (e.g. academic entrepreneurs, university TTOs, venture capital funds, etc.) through organizing dedicated focus groups with the help of which existing gaps and needs are identified. Eickelpasch and Fritsch (2005) explore the example of such field-specific grants in Germany by looking at the implementation of the Bioregio program designed to provide financial support for the commercialization of projects in the biotechnology field. The authors argue that this type of policy may have a significant impact and that it can thus be regarded as a rather efficient instrument of public support for technology transfer from university to industry.

There is also a group of academic studies which look at *grants aimed at individual researchers*. The already mentioned paper by Rasmussen and Rice (2012) reports about the FORNY leave-of-absence grant in Norway, the objective of which is to support researchers in commercializing their idea by covering the cost of the employer in order to make 20% to 100% of the researcher's position available to work on a commercialization project. In a similar vein, Clarysse et al. (2007) provide the example of Germany, where the German government, through its EEF-Fund, granted individual researchers with scholarships to start a spin-off. The same study also analyzes the case of Belgium, where a special type of a post-doc grant has been introduced - *a Spin-off PostDoc* - which can be used by a researcher to start a spin-off, while some other Belgian universities (e.g. University of Ghent and Antwerp) receive *government-funded mobility scholarships* from the

Flemish Government, which allow post-doc researchers to be employed in a company within the field of their research, keeping, however, the option of returning to the university (Clarysse et al., 2007).

Rasmussen and Sorheim (2012) describe the case of the *Enterprise Fellowship Program* in Scotland which helps individual academic researchers to develop spin-offs by covering a 12-months salary to develop the idea (including business training), as well as providing the important links to the networks of business angels. As one of the main conclusions of their study, focused on the whole range of financial measures in support of commercialization of university research, the authors highlight the importance of introducing more initiatives addressing the lack of competencies to make university projects “investor ready” (Rasmussen and Sorheim, 2012).

The type of studies discussed above illustrates the example of the public measures aimed at fostering informal technology and knowledge transfer from academia to industry, also providing adequate incentives to researchers to engage in this type of activities. We next examine to what extent the issue of public financial support for formal commercialization of university research has been discussed in the existing academic literature, and which relevant critical issues and gaps arise from the review of the studies on the matter.

5.2.2. Pre-seed and Seed Financing

In most countries public authorities have been setting up pre-seed financing schemes and seed capital funds in order to address the funding gap resulting from the general reluctance by private venture capital investors to finance the early phases of projects stemming from university research, discussed in detail in Section 3 of the present study (Clarysse et al., 2007; Myers, 1984; Wright et al., 2006; Lockett et al., 2002; Moray and Clarysse, 2005). For instance, it has been highlighted in the literature that the inability to obtain finance capital is one of the major reasons why many university start-ups are abandoned (Shane, 2004). Such motivations are at the basis of the direct intervention of the government in stimulating the emergence of academic start-ups and adequate sources of financing for them (Lerner, 2009). Previous studies by Knockaert et al. (2010) on a sample of start-ups from various European countries, or by Munari and Toschi (2011) on a sample of new ventures from the micro and nanotechnology sector in the United Kingdom found that, in contrast to purely private VC funds, publicly funded VCs tend to be more willing to invest in early-stage university start-ups, indicating empirical evidence in support of the governments' intentions to bridge the funding gap (Rasmussen and Sorheim, 2012).

With the aim of closing the gap in the initial financing, national governments and regional authorities have been implementing various public policy measures, either by providing direct financial support, or by stimulating venture capital interest in academic spin-offs through indirect measures, namely financial incentive schemes. With that, as is being pointed out by Rasmussen and Sorheim (2012), although public funds have become an important source of early-stage funding for university start-ups, little systematic research has been done to investigate the range of government funding initiatives and their impact on the growth and success of university spin-offs.

Among a few existing studies that provide a detailed account of the public measures addressing the financing gap, stands out a study performed by Wright et al. (2006). The authors provide a classification of the existing public financing measures in support of commercialization of academic research based on the amount of public participation. More specifically, they suggest to distinguish between the 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 the public-private partnerships with a reduced public participation, varying from 10% to over 90%, depending on the country. Thus, the University Challenge Funds (UCF) in the UK consist of up to 77% of public capital, while the University Seed Funds in Belgium (Flanders) have an average public participation in the amount of 20%. However, the authors underline evidence on the still existing mismatch between the demand and supply side of the venture capital market.

In the UK, as underlined in the study by Mustar and Wright (2010), the University challenge fund is arguably the most world-famous initiative in the field of public policy to foster technology transfer by establishing a seed capital fund to encourage the exploitation of scientific discoveries in universities. Within this granting scheme, universities receive a challenge fund to support spin-offs. In Belgium, a the study by Write et al. (2006) reports, the Universities of Ghent, Brussels and Antwerp each have their respective seed capital funds with over 2.5–5 million of seed capital at their disposal to invest in spin-offs, which in 2005 have been leveraged by a Flemish SBIC-type of initiative allowing these funds to increase their capital with an equal amount of public money. In addition, in January 2006, a public fund was started to co-invest with each of these university funds in spin-offs (Wright et al., 2008). In France, according to the study by Mustar and Wright (2010), the public grants for the funding of the creation of academic spin-offs were generally obtained through a national competition which identifies the best projects and awards them a grant. The best projects could then be hosted in public incubators, and after the creation they can receive further financing from seed money funds (Mustar and Wright, 2010).

As evidenced by Rasmussen and Rice (2012), in Norway, where there are joint seed capital funds between the government and private investors, too, the government provide loans with a risk reducing mechanism, while private investors provide equity capital to the funds. The goal is to stimulate private investors to invest in early phases of new venture development. It is also assumed that private investors will provide competence to the new firms.

Hulsink et al. (2008) have studied the TechnoPartner Knowledge Exploitation Subsidy Arrangement (SKE) in the Netherlands which encourages the utilization of publicly financed scientific knowledge by existing companies. The pre-seed facility, available within this public initiative, provides pre-seed capital to high-tech start-ups, including those in the academic sector,

while the so-called patent fund provides financial resources to public knowledge institutions so that they could finance the costs associated with patent applications (Hulsink et al., 2008).
Besides granting direct financing support, many of the public support programs targeting academic start-ups are designed to provide a comprehensive framework to enhance the effectiveness of the early stage of the technology transfer process through additionally providing facilities, management expertise, legal advice and mentoring. Among the best known examples of such government support programs are the TULI program in Finland (Salo et al., 2006), the University Challenge Funds in the UK (Wright et al., 2007), the Twinning Seed Fund and Biopartner programs in the Netherlands. However, Lotta (2003), who analyzes such types of government support programs, reports a concern that a too extensive public sector activity may have a "crowding out" effect with regard to the private business, such as the market for startup consultants and service providers. The author points out that the government should instead focus more on providing support and services in such areas as the collection, systematization and dissemination of information, and in coordination of programs aimed at increasing networking among various players within the innovation cycle.

As the review of the literature demonstrates, no academic study so far has addressed in detail the governance and design of university-promoted seed funds, their investment strategies and ultimate impact, which calls for the need of future research specifically designed to address the issues of the effectiveness of the financing measures.

Proof-of-concept funds

There is a growing body of academic papers analyzing a particular set of mechanisms that have been recently developed in several countries under the label of Proof-of-Concept Funds (PCF) or similar names (such as translational fund, proof-of-principle fund, fonds de maturation, and other), which focus specifically on the early stages of the technology transfer process in order to identify and evaluate technologies for application in new products and services as well as to prepare the actual transfer of technology and knowledge. A Proof of Concept Fund (PCF) has typically the objective to provide funding to a project in order to assess the commercial potential of the idea, demonstrate the feasibility and value of the technology, facilitate the definition of the business plan and strategic plans, lead to the formation and registration of a new company.

Uecke et al. (2010) analyze a new program, called "ForMaT – Research within a Team for the Market", recently initiated by the German federal ministry for education and research with the goal of fostering knowledge and technology transfer. The commercialization grants obtained through this program focus specifically on early stages of the technology transfer process to identify and evaluate technologies for application in new products and services as well as to prepare the actual transfer of technology and knowledge. The commercialization grant partly bridges the finance gap and provides funding for the transfer project to achieve a stage in development where commercialization is possible. The structure of the program ensures interdisciplinary teams where business developers are integrated early in the team performing economic evaluations and preparing for commercialization. The programs such as ForMaT, through providing means to evaluate the potential early enough to boost the innovation process, establish a framework for enhancing effectiveness of early stages of the invention and technology transfer processes.

Rasmussen (2008) discusses the similar initiatives in Canada, where general agencies such as the Industrial Research Assistance Program (NRC-IRAP) and the Business Development Bank of Canada (BDC) provide considerable support to research-based spin-off firms. As reported in the study, a considerable share of Canadian university spin-offs have received the IRAP support, which is provided to the projects carried out in cooperation between academics and companies. The author point to the general positive impact of this public policy measure reporting that the spin-offs which received such government support generally perform better, and 72% of the startups, supported through this measure, have received VC funding compared to 44% of the whole sample of spin-offs.

Hulsink et al. (2008) describe an entrepreneurship stimulation program TechnoPartner set up by the government in the Netherlands in 2004 and designed to promote knowledge and technology transfer through spin-off creation by universities and research institutes, addressing the financial and information-related obstacles the academic spin-offs may encounter (e.g. improving the markets for seed and early stage financing; providing specific information and advice for the academic researchers participating in the program, etc.)

The Idea to Innovation (I2I) program in Canada aims to fill the similar gap, where the university academics may have an idea, but no exposure to industry, as well. Thus, the I2I program provides financing and other kinds of assistance to the university research and development projects with technology transfer potential so that they could be further developed for the creation of a spin-off or for the licensing process (Rasmussen, 2008; Rasmussen and Sorheim, 2012). The funding within the Phase I of the I2I program happens at the proof-of-concept stage and is available for up to 12 months, while in the Phase II, through the initiative called the Early Stage Investment Partner, the government can support up to two-thirds of the costs of the project in case of the creation of a spin-off company. For further cooperation with an existing company, NSERC may fund up to half the cost of the project with the company providing the other half through a combination of cash and in-kind contributions (Rasmussen, 2008). Although it is the academics that apply for funding and administer the awarded grants, the applications have to be signed by the university TTO since it is expected that the TTOs will only sign on the projects that they believe have commercial potential.

Rasmussen and Sorheim (2012) analyze another dedicated government granting program in Canada which provides financing to advance discoveries/inventions towards commercialisable technologies is the Proof-of-Principle Program (POP). The POP program awards the funds in two phases. Phase I grants fund proof of principle research projects of up to 12 months' duration, with a view to attract new investment and create new science-based businesses, while in the phase II, grants are provided for up to 12 months at the co-investment stage undertaking follow-on proof of principle activities in partnership with a nonacademic investor. This funding opportunity aims to provide a platform to better enable the academic institution/researcher to move the discovery/invention further down the innovation pipeline. The grants are awarded to the individual researcher, but the funding authority requires a letter of intent signed by the university TTO. In Scotland, there exists as well a dedicated program which provides funding for the pre-commercialisation phase - Scottish Enterprise Proof-of-Concept Program (PoC). As reported in the study by Rasmussen and Sorheim (2012), £28.1 million has been awarded to 172 projects since 1999 within this government program, however, no evidence is provided on the subsequent success of the projects that received financing.

Traditionally, the effectiveness of the public policy measures aimed at providing financial support to the universities has been measured by the number of spin-offs created with the received funds. Thus, as report Wright et al. (2008) in their study on the funding schemes with the government participation, the registered outcomes of the HEROBC initiative in the East Midlands in the UK supported 9 spinoffs, generated 15 licensing opportunities, and secured £908,000 of seed capital/industry funding. As a result, a portfolio of projects has been developed, securing £2.3 million in matched/follow-on funding.

In general, the impact of the public policy measures aimed at addressing the financing gap at the initial stages of an academic start-up has been considered as positive. In particular, Huggins (2006) tests the hypothesis that private sector seed funding for knowledge commercialization is more likely to be obtained if the public funding is already in place. The survey data reveals that those universities gaining significant amounts of public funding are more likely to also access private funding (Huggins, 2006). The results of the review performed by Borlaug et al. (2009) show that those academic start-ups that demonstrate a higher degree of commercial success tend to be better endowed with public financing through dedicated government schemes and seed fund investments. One of the explanations offered by the existing research is that the presence of a public sector funding acts as a signal for private sector involvement, i.e. the probability of receiving private sector investment increases with the amount of public funding secured, due to the reduced risks of involvement and the signal of legitimacy of the investment (Leleux and Surlemont, 2003). In the qualitative study by Huggins (2006), performed among the representatives of London venture capital community, most interviewees stated that the majority of venture capitalists do not regard seed funding of academic start-ups as attractive unless there is a level of public sector involvement.

The contrasting evidence on the impact of the public participation in pre-seed and seed funding of the academic start-ups states that the provision of public capital for the creation of an academic spin-off may lead to an overvaluation of IP at a start-up phase, which is reflected in the amount of capital with which such spin-offs are generally founded. Clarysse et al. (2007) argue that this overvaluation at the initial stage, in turn, does not positively influence the short-term performance of the spin-offs (as measured by their capital raising at a post-start-up stage). This points to an emerging issue that the availability of suitable funding sources may have become less of a problem at the very early stage but that problems are posed at the next stage where the venture begins to need significant levels of funds to enable growth potential to be realized, but due to initial overvaluation faces difficulties in obtaining subsequent financing (Clarysse et al., 2007). Another concern, as argued, for instance, by Lotta (2003) in the study of Finnish policy measures, is that the use of public funding in the past does not increase the probability of the use of private sector services but increases instead the likelihood of a continuing use of public funds. These open questions call for additional analyses and empirical evidence on the effectiveness of the existing public financial support measures towards the commercialization of university inventions.

5.2.3. Funds oriented to create TT facilities and infrastructures

As our review has revealed, another type of public policy measures, extensively covered in the existing academic literature, refers to those *financing technology transfer facilities and infrastructure initiatives*. In line with the changes in legislation and in addition to such regulations, most European governments started subsidizing the "interface" services – such as TTOs - to establish or further develop their activities (van Zeebroeck et al., 2008; Wright et al., 2008). Lissoni et al. (2009) provide the example of Denmark, where, like in some other countries, the government provided substantial funding for the creation of a technology transfer infrastructure following the introduction of institutional ownership.

Besides providing finance for the initial stage, e.g. creation of a technology transfer office at the local universities, certain countries (e.g. Italy, France, Germany and Belgium) have implemented a number of measures to further stimulate the professionalization of TTOs. In particular, as Clarysse et al. (2007) highlight, universities in some countries started to grant TTOs with extra funding so that they could apply for patents and/or provide incubation services to potential spin-offs. The research evidences that besides the expected impact, such measures resulted in a further increase in the importance attached to patents and IP more generally (Clarysse et al., 2007; Wright et al., 2008).

Another form of government support within the present group of public policy measures is aimed at creating technology transfer facilities and infrastructure through providing financial aid to university *incubators* and *science parks*. These intermediate organizations, that provide the technological and organizational resources, as well as managerial expertise for the startups (Phan et al., 2005), address the issue of an innovation market failure, when the commercial value of the technology, upon which a start-up is being created, is characterized by a high degree of uncertainty rendering the calculation of a discount rate difficult, which results in a failure of the market to provide financial and other kinds of support for the commercialization of the technology. In this situation, the incubation process may be the only way a start-up, that exploits an embryonic technology (and this is very often the case of academic start-ups), can emerge (Phan et al., 2005). As the existing studies highlight, government support for the incubators and science parks, which in most cases are directly linked to universities (Wright et al., 2006), represent another viable type of public policy measures aimed at facilitating commercialization of university inventions.

As reported by Jacob et al. (2003), in the late 1990s the governments in France and Sweden launched their National Incubation Programs with the goal of decreasing the so-called knowledge gap and facilitating technology entrepreneurs in starting up a business. The authors highlight that academic spin-offs that enroll in such a program benefit from business support and low cost facilities. Regarding the effectiveness of this type of measures, Mustar (2002) in his study of French incubators reports that at the end of 2001 the 31 incubators in place at that time had already hosted 440 projects, over half of which were winners of the national business creation competition.

Abetti (2004), looking at the case of Finland, shows that for almost three decades the government has supported the development of an extensive network of business incubators as well as provided support for the training of incubator managers through a multi-year grant of the Ministry of International Trade and Industry. This represents the proactive approach exemplified by funding and incentives for incubators in Finland, which has been argued to be a viable method for not only enhancing university technology transfer, but accelerating economic growth and entrepreneurship on a broader scale (Abetti, 2004). The studies by Borlaug et al. (2009) and Rasmussen and Rice (2012) talk about the role of the Norwegian government which participates in the funding of university incubators and science parks connected to the largest research institutions through its agency SIVA acting as a part owner of the above infrastructure initiatives.

As for the effectiveness of this type of measure, the study by Aernoudt (2004) reports that, as of that year (2004), none of the US technology incubators (including those established in the early 1980s) have reached full financial self-reliance.

Science parks are another type of support infrastructure for the start-ups covered in the literature. As a rule, the science parks are usually created close to the universities and they get a substantial portion of public funding. Thus, Bigliardi et al. (2006) look at the science parks in Italy and they find that most of the financial resources of Italian science parks come from public funding (e.g. Scientific Park of Trieste, VEGA science park, Galileo). Thus, public research funds (regional, national and from the European community) play a major role in supporting the Science Park of Verona which has the right to these funds by winning public competitions for them.

Although some scholars have underlined the critical role incubators and science parks play as the support mechanisms for an academic start-up, there has been a recent debate in the literature on whether these infrastructure facilities may be considered an efficient tool for enhancing the start-up performance, as it has been previously argued (Cooper, 1973, 1984; Meyer, 2003). The results of the study by Siegel et al. (2003) performed in the United Kingdom demonstrate that science park firms report slightly higher research productivity than comparable firms not located on these facilities, as measured by new products, services, and patents. However, a major shortcoming of this study is that it is based on the longitudinal dataset that dates back to the 90s, so the analysis of the performance indicators based on a more recent data, as well as in other national contexts, is needed in order to be able to draw conclusions about the relative performance of start-ups located in university science parks.

Another major concern regards the exit rates of the science parks which, as reported, remain rather low. For instance, Phan et al. (2005) and Vohora et al. (2004) argue that the reason for low exit rates may lie within the existing incentive system, encouraging the science park managers to maintain full occupation capacity. As the scholars point out, the most obvious issue regarding the effectiveness of these infrastructure initiatives is the governance question of incentives and measures of science park or incubator performance, as well as the organizational capabilities to develop their tenant firms to the "exit" point (Phan et al., 2005; Vohora et al., 2004).

Another issue highlighted by Phan et al. (2005) and pertaining to the incentive structure and performance relates to the fact that, given that incubators and science parks are often the result of public–private partnerships, it is likely that there are multiple principals which may lead to a ''principal–principal'' agency problem manifested in the opportunistic behavior of the controlling shareholders. To the extent that in case of science parks and incubators the principles of good corporate governance, as a rule, are neither formalized nor embedded in the management routines of these organizations, the principal conflict may result in inefficiency of the resource allocation decisions of incubator and park administrators which, in turn, will lead to the decreased efficiency and performance of the organization (Phan et al., 2005).

However, in spite of the issues regarding the actual efficiency and effectiveness, the academic literature agrees on one of the major benefits that science parks and incubators may offer to academic start-ups, i.e. the professional assistance in spotting and getting integrated in the established business networks. This takes on a particularly relevant meaning since, as underlined by various researchers, the ability to access external finance through networks is regarded as an important predictor of the performance of start-up firms (Lee et al., 2001; Elfring and Hulsink, 2003).

With regard to providing access to valuable networks, besides the science parks and incubators, there are some other government-supported initiatives which have been introduced in order to facilitate the integration of academic start-ups in the local finance and business communities. Thus, Van Looy et al. (2003) in their study on Belgium, talk about the government sponsored project called Leuven.Inc created in 1999, in which the local business environment, professional advisors and the university are undertaking a number of joint initiatives aimed at increasing the development of the region. The project is supported by the municipal and provincial governments and besides providing the infrastructure, it is aimed at stimulating actively the exchange of ideas and the creation of networks (both formal and informal).

In Sweden numerous organizations to support technology transfer were established during the 1990s. For instance, a series of technology bridging foundations (Teknikbrostiftelser, TBS)was founded in 1993 to help universities build links with industry and other stakeholders, while a recent development is national competence centers which are financed jointly by industry, university and government (Jacob et al., 2003),.

To sum up, in addition to their primary role of technology transfer - typically from university and R&D laboratories to high-tech entrepreneurial startups – such support structures as incubators, science parks and other similar infrastructure facilities provide for job creation, regional economic development, and export promotion. However, as our review has revealed, there exists only limited empirical evidence in the literature assessing their actual contribution to successful knowledge transfer and economic development, which calls for further, more in-depth research on their actual impact.

5.2.4. Financing of University-Industry Collaboration

In fostering technology transfer and more active commercialization of university knowledge, another important tool, widely discussed in the literature, is government support aimed at creating and developing industry–university research and technology partnerships (Bozeman and Gaughan, 2007). Through this type of public policy measures, the national governments promote a fruitful interdisciplinary framework for the technology transfer processes (Uecke et al., 2010).

In the US, among the most cited programs are the Small Business Administration’s Innovation Research program, discussed, for instance, in Link and Scott (2000) and Audretsch et al. (2002);

the Small Business Technology Transfer research (STTR) grants that provide support to cooperative early-stage R&D efforts of an SME with a university partner (Wright et al., 2008); the Cooperative Research Act (Scott,1989; Crow and Bozeman, 1998), and the NSF industry–university cooperative research centers program (Gray and Walters, 1998; Feller et al., 2002). In Europe, there is academic evidence on *the LINK scheme*, established in 1986 to support collaborative research and development projects between industry and universities in areas of strategic importance, and the Knowledge Transfer Partnerships introduced in 2004 and aimed at providing companies with government support with access to the knowledge, resources and expertise available in universities to develop new products and working processes (Mustar and Wright, 2010). For the Netherlands Hulsink et al. (2008) provide evidence on the Subsidy Regulation Infrastructure Techno-starters (SIT) initiative that provides subsidies to the knowledge institutions for their support to new technology firms.

A limited attention in the academic literature has been given to the *tax deduction schemes* as a government, fiscal, instrument to support collaboration between universities and industry. Thus, Rasmussen and Rice (2012) talk about the Skattefunn in Norway which is designed in a way that the level of reimbursement of the expenses to the R&D activity in the form of tax deduction or a direct grant is higher when a research institution is involved. Another national example is presented in the study by Van Looy et al. (2003) who look at the case of Germany where there are R&D soft loan schemes aimed at instilling the cooperation between the academia and industry.

Among the policy measures to induce collaboration between universities and industry are also the so-called *technology programs*. For instance, as shown in the research by Salmenkaita and Salo (2002), in Finland the Tekes technology programs of the National Technology Agency favor collaborative projects, that is the projects submitted by universities are typically funded on the condition that these proposals are supported by one or more industrial partners, while large firms are encouraged to establish subcontracts with universities in their research projects in order to receive more financing from the government. The study by Eickelpasch and Fritsch (2005) focuses on the German context, where the EXIST program, introduced in 1997, was to improve the knowledge transfer between universities and the commercial sector by promoting entrepreneurship and encouraging the creation of start-ups by students and academic personnel.

With the clear value-adding objective of bringing the incentive structures of the academia and industry in line with what regards the collaboration, there have been however doubts expressed as to the overall effectiveness of these programs. For instance, as Salmenkaita and Salo (2002) note, such technology programs often have received wide critiques with regard to their very often rigid structures and premature selection of technological options which may have a negative influence on the overall effectiveness of this type of policy measures. Another drawback which the authors highlight refers to the fact that such programs favor R&D activities in established rather than emerging industries, which is quite short-sighted and in conflict with the program's ultimate goals and which may have a major negative impact on the national innovation system in the long-term period (Salmenkaita and Salo, 2002).

5.3. Competence-building measures

Another distinct group of public policy measures, revealed during the review of the academic literature on the government activities for facilitating knowledge transfer has revealed that there is a group of government-funded measures aimed at covering the so-called "knowledge gap" through training and educating of academic researchers and TTO personnel in the aspects of technology transfer and commercialization. As a rule, the governments allocate national and regional funds for such competence-building programs, as an independent program, or under a more general program in support of innovation and entrepreneurship.

We have been able to track only a very restricted set of studies that address this type of measures. Some of the examples of such policy measures studied in the literature include the Danish Action Plan for Entrepreneurship, the SPINNO Training Program in Helsinki, Finland, and the Science

Enterprise Challenge in the UK funding the universities, discussed in Mustar (2002). The previously mentioned IPM program in Canada, studied by Rasmussen (2008), has launched and sponsored the internship programs in technology transfer which must be undertaken by consortia of universities, colleges and/or hospitals,s possibly in collaboration with non-academic organizations. The training should include hands-on experience with appropriate mentoring in the institutions involved and in organizations such as small- and medium-sized enterprises, government departments, venture capital firms, and/or other suitable organizations in Canada or abroad. In this manner, besides supplying training and essential knowledge in the field of technology commercialization, such initiatives serve as a networking tool that provides opportunities to establish and/or strengthen the links with the external stakeholders (e.g. industry players, venture capital funds, government authorities, etc.). Other examples of Canadian government programs, discussed in the study by Rasmussen (2008), are the Science to Business (S2B) program and the Commercialization Management Grant program which were crafted to increase the knowledge and skills in commercialization among spin-off management and TTOs staff. The S2B program enables recent health research PhDs to pursue an MBA aiming at developing science-trained entrepreneurs, while The Commercialization Management Grant program provides university TTOs with the opportunity to recruit up to two recent MBA graduates to work with the commercialization of intellectual property which results from the publicly funded research (Rasmussen, 2008).

Mustar and Wright (2010) have studied the experience with this type of measures in the UK, analyzing The Medici Fellowship Scheme that was introduced in 2005 in order to address the issue of the lack of effective communication between the academia and industry. Thus, the initial pilot scheme provided 50 fellowships and was focused on the commercialization of biomedical research in five UK universities providing commercial training and encouraging fellow researchers to develop links with practitioners from the biotech business community and other external stakeholders (Mustar and Wright, 2010). Another example of the public policy measure described by the authors and aimed at instilling entrepreneurial culture among the academics and making it a legitimate career choice to opt for academic entrepreneurship is the Science Enterprise Challenge (SEC) initiative which was established by the UK government in 1999. One of the main goals of this public policy measure is to provide potential academic entrepreneurs with the contacts to the members of the finance community (e.g. seed funds, venture capitalists, business angels), as well as the access to the science park accommodation. As Mustar and Wright (2010) highlight, such publicly supported schemes may play a crucial role in developing links with industry players with regard to such collaborative activities as, for instance, possible mentoring schemes, various seminars and master classes delivered by the practitioners from the field, as well as sponsorship of business plan competitions at the universities.

With that, we were not able to find any academic studies that would address the issue of the effectiveness of such support measures, posing thus an important avenue for future academic research. in order to advise public policy with regard to the impact and optimal design for the best possible outcome.

6. Discussion, Implications and Future Research

Some scholars have argued that with so many public support measures in place, it is not surprising that academic spin-off and other forms of technology transfer activities have been increasing in Europe (e.g., Clarysse et al., 2007). However, as revealed in the present review, one of the main issues arising is the difficulty in assessing the overall effectiveness of the public policy measures at the general country level, at the level of a single university, or individual schemes. Due to this, there is still a considerable gap in the academic literature devoted to public policy measures for knowledge transfer as to the actual assessment of the overall effectiveness of the actions. It appears to be a complicated task to disentangle the effects of a single public policy intervention since many of the government measures have been implemented in parallel and also coincided with the changes in IPR regulations (Geuna and Rossi, 2011). This highlights the importance of adopting *a* *comprehensive and integrative approach* when judging the impact of government support measures, by looking at the long-term impact of all types of measures being implemented, and by considering the interaction effect of both legislative/institutional and direct/financial ones.

The review has revealed the presence of another methodological issue regarding the assessment of the relative impact of the government policy measures in support of technology transfer. More specifically, Rasmussen and Rice (2012) argue about the failure to account for a full picture by the means of purely quantitative measures (e.g. number of patents, licenses, spin-off firms, and the revenue generated) to evaluate the outcome of technology transfer activities, since a whole range of other, non-market, modes of interaction between academia and industry exist (e.g. industry consulting, transfer of graduated students) and their relative effectiveness is much more difficult to capture. This presents the necessity for the future research to be carried out to address the issue of developing more precise and comprehensive evaluation criteria to have a more precise and better-measured picture of the effectiveness of the public policy measures.

Another critical issue regarding the assessment of public support measures is the differences in institutional contexts, the historical paths in the government support of academic entrepreneurship and technology transfer, the differences in the intensity and design of such policy measures, as well as their integration within the general national innovation policy (Wright et al., 2006). The latter consideration reveals another issue, namely the *complementarity* of measures destined for various levels (e.g. national/regional/local). In order to mitigate the risk of fragmentation in policy implementation and resource allocation (Munari and Toschi, 2012), it is important that the policy makers, when crafting specific measures and designing support mechanisms, take into consideration the complementary nature of such policies in order to provide for more coherence and synergy at the implementation stage. A vast range of public policy measures simultaneously undertaken at many levels (national, regional, local) may create confusion among different actors (e.g. as argued by Rasmussen (2008) in the case of Canada), as well as it may result in a fragmentation of financial resources (with too many programs of limited size and impact) and high level of overlapping between various programs and schemes which may lead to the reduced effectiveness of such measures (Lotta, 2003). This points to the importance of adopting a comprehensive approach towards policy formulation and implementation through designing and implementing a *coherent overall strategy* aimed at enhancing technology transfer and commercialization of university knowledge.

The present review of the existing academic research demonstrates that there is a considerable body of literature that provides description of the design and characteristics of the measures in support of technology transfer, but much fewer studies are dedicated specifically to the evaluation of their impact and relative effectiveness. In addition to the above mentioned, one of the reasons for this may be the relative recent character of many policies, making it difficult to obtain relevant track record and to perform the effective evaluation of their impact (Mustar and Wright, 2010). It may also be that such a lack of research on the impact of the public policy measures is due to the difficulty in obtaining data in order to perform such evaluation. Another hurdle is the varying difference across countries in terms of their approaches to facilitate university technology transfer (Geuna and Muscio, 2009), which creates a situation in which the design and implementation of certain initiatives are based on benchmarking and experimenting instead of solid conceptual frameworks. However, as the researchers highlight, there is still a long way to go to integrate disparate practices into conceptual frameworks that can lead to improved performance of these programs and improved return on the investment of the government resources (Rasmussen and Rice, 2012). At last, as the evidence shows, in some countries the public support programs do not have an exclusive focus on academic start-ups, but rather on all innovative start-ups in general (e.g., Mustar and Wright, 2010 for France), which creates further obstacles in performing evaluation of the impact of such government support measures on university technology transfer.

In this manner, as our study shows, there arise important research gaps related to the effective evaluation of the impact of the public policy measures, both in terms of lack of the academic research and the absence of unified evaluation practices and outcome criteria. Among other gaps identified with the present study is the scarce attention to the analysis of the design, characteristics and effectiveness of the legislative acts governing issues other than those related to IPR ownership, as well as the research on the design and impact of the competence-building measures, which prove to be an important area of public intervention for efficient and effective knowledge transfer.

The key research issues and gaps identified in the present study open up a promising field for further academic analysis of the government support measures aimed at fostering technology transfer and commercialization of university knowledge. In particular, based on the results of the review performed, the following issues emerge.

First, due to the identified gap in the academic research of the effectiveness of the public policy measures, future studies should address in more detail the issue of the impact of university IPR reforms on the actual commercialization rates of academic patents and effectiveness of technology transfer activities, e.g. in terms of commercial use through licensing, sale or spin-off formation. Also, the design, characteristics and effectiveness of other legislative measures, not just related to the ownership of university IPRs, should receive more attention in the future research, such as the degree of autonomy of universities or the legal status of researchers and TTO managers.

Another promising direction relates to the assessment of the impact of specific funding-related initiatives (e.g., seed funds, subsidy schemes, proof-of-concept funds). For instance, it would be interesting to see whether the extent of the impact of such policy measures varies according to the level of implementation (national/regional/local) and/or according to the types of universities involved, e.g. single universities or group of universities. Besides, considering the lack of scientific research on the competence building measures, more attention should be devoted to the analysis of the optimal structure of this group of public support, along with the assessment of their impact.

Finally, taking into consideration the above findings, the present research provides important implications for the national governments and public policy makers in what regards the design and implementation of the measures in support of technology transfer, as well as the assessment thereof. In particular, a comprehensive and integrated approach towards policy formulation and implementation (legislative framework; funding; competences) should be adopted, striving for coherence and synergy between national, regional, local and university-level policies and measures. In order to address the issue of institutional differences and path dependencies**,** tailor-made solutions instead of a «one-size-fits-all» approach should be opted for, along with a dynamic and flexible set of initiatives due to constant changes in operational setting (Rasmussen, 2008). Moreover, as identified by the present research, there is a need to develop better-fitted and more precise indicators to take into account the interplay of the full array of knowledge transfer channels and mechanisms (e.g. Mowery and Sampat, 2005). The timely and complete data availability for researchers, university administration and policy-makers thus becomes an important pre-requisite in order to actually assess the impact of public policy measures and to be able to undertake benchmarking exercises in order to identify successful experiences and best practices to build upon in the future.

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ANNEX

Table 2 - Overview of studies on Public Policy Measures across Countries

Author(s)	Year of publication	Country (-ies)	Type of measure(s)
Abetti	2004	Finland	financing of TT infrastructure
Audretsch et al.	2002	US	commercialization grants/subsidies
Azagra-Caro et al.	2006	France, Spain	IPR legislation
Azagra-Caro	2010	Spain	IPR legislation
Balconi et al.	2003	Italy	IPR legislation
Baldini	2006	Denmark	IPR legislation
Baldini et al.	2006	Italy	IPR legislation
Baldini et al.	2010	Italy	IPR legislation; university autonomy legislation;
Bigliardi et al.	2006	Italy	financing of TT infrastructure
Borlaug et al.	2009	Norway	financial support measures
Carayol and Matt	2004	France	IPR legislation
Cesaroni and Piccaluga	2003	France; Spain	IPR legislation
Clarysse et al.	2007	Belgium, France, UK, Italy, Germany	IPR legislation; researcher's status legislation; legislation on TT infrastructure; commercialization grants/subsidies; seed and pre-seed capital;
Czarnitzky et al.	2011	Germany	IPR legislation
Damsgaard and Thursby	2012	Sweden	IPR legislation
Debackere and Veugelers	2005	Belgium	IPR legislation; researcher's status legislation
Della Malva et al.	2008	France	IPR legislation; financing of TT infrastructure
Eickelpasch and Fritsch	2005	Germany	financing support for university-industry collaboration projects
Gallochat	2003	France	IPR legislation; TT infrastructure legislation
Geuna and Rossi	2011	US; EU	IPR legislation
Goldfarb and Henrekson	2003	US; Sweden	IPR legislation; financing support for university-industry collaboration projects
Huelsbeck and Lehmann	2006	Germany	IPR legislation
Huggins	2006	UK	pre-seed and seed capital
Hulsink et al.	2008	the Netherlands	pre-seed and seed capital; financing support for university-industry collaboration projects

Jacob et al.	2003	Sweden	IPR legislation; financing of TT infrastructure
Lissoni et al.	2008	France	IPR legislation
Lissoni et al.	2012	Italy	IPR legislation; univeristy autonomy legislation;
Lotta	2003	Finland	financial support measures
Mcdonald	2009	UK	IPR legislation
Meyer and Tang	2007	UK	IPR legislation
Mowery and Sampat	2005	US	IPR legislation
Mustar	2002	EU, Canada, US	researcher's status legislation; legisaltion on creation of TT infrastructure
Mustar and Wright	2010	France; UK	researcher's status legislation; financing of TT infrastructure; pre-seed and seed capital; financing support for university-industry collaboration projects; financing of competence building programs
Ranga et al.	2003	Belgium	IPR legislation
Rasmussen	2008	Canada	commercialization grants/subsidies; proof-of-concept funds; financing of competence building programs
Rasmussen and Rice	2012	Norway	financial support measures
Rasmussen and Sorheim	2012	Canada, Finland, Ireland, Norway, Scotland and Sweden	proof-of-concept funds; pre-seed and seed capital
Saragossi and van Pottelsberghe de la Potterie	2003	Belgium	IPR legislation
Tang	2008	UK	IPR legislation
Toole and Czarnitzki	2005	US	commercialization grants/subsidies
Uecke et al.	2010	Germany	proof-of-concept funds; pre-seed and seed capital
Valentin and Jensen	2007	Denmark	IPR legislation
Van der Steen et al.	2008	the Netherlands	financial support measures for university-industry collaboration project s
Von Lebedur et al.	2009	Germany	IPR legislation
Von Lebedur	2009	Germany	IPR legislation
Wright et al.	2006	UK and Continental Europe	financial support measures

Academic patent nonuse: the role of collaborations with external parties during the inventive process

Academic patent nonuse: the role of collaborations with external parties during the inventive process

Abstract

As recent studies show, universities demonstrate one of the highest rates of underutilized patents. With that, the issue of under-commercialization of university patents remains largely under-explored. Considering the basic nature of most academic research, as well as the growing role of academia as an important generator of innovations, the nonuse of academic patents results to be a crucial issue to focus upon, both from an academic and policy standpoint. The present study addresses this research gap, by exploring the role of different types of knowledge for academic inventions and their effect on the subsequent success or failure of a patented invention to get commercially exploited. In particular, we argue that the type and nature of collaborations with external parties during the inventive process will determine the subsequent "destiny" of a resulting patent. We employ a rich dataset of the patents by inventors from universities and public research organizations with the priority dates 2003-2005 across Europe, US, Israel and Japan. The results of our analysis point to the necessity of a deeper research on the effect of various types of interactions between academic inventors and external stakeholders on the rate of commercial exploitation of academic patents, providing important implications for university administration and public authorities with regard to crafting and implementing measures to exploit academic research more effectively.

Keywords: University patenting, Academic patent nonuse, Commercialization of academic research

1. Introduction

In times when the economic growth depends on continuous introduction of innovations, the role of universities, as major generators of inventions, has been broadly discussed within both academic and policy literature (OECD, 2003; Etzkowitz et al., 2000). In particular, since it is not an invention in itself but rather an application of such technological inventions through commercialization that creates wealth in various forms (Heslop et al., 2001), the knowledge and technology transfer from universities to industry has become one of the central issues of the academic research (e.g. Agrawal, 2001; Cohen et al., 2002; Perkmann and Walsh, 2009; Phan and Siegel, 2006; Rothaermel et al., 2007).

With that, recent studies show that universities demonstrate one of the highest rates of underutilized patents. According to the research performed in Europe, over 50% of university patents remain commercially unexploited (Giuri et al., 2007). According to this study, while the majority of unused patent stock of universities is represented by "sleeping" patents, there is also a share of patents which have been reported as "blocking". If seen with regard to the industry firm, this latter finding may be perfectly logic and expected, since the competitive behaviour and the very nature of the business can make patent blocking a necessary choice; however, in the case of universities such situation may seem quite surprising. It has been believed that universities, given their non-commercial mission and lack of complementary assets, do not generally engage in strategic behavior associated with non-use of patents for blocking reasons (Bercovitz and Feldman, 2005). The traditional, core mission of a university has been that of knowledge dissemination which stands in clear contrast with the "withholding" behavior dictated by strategic considerations (e.g. blocking competitors). With that, the evidence on the existence of a share of blocking patents in the academic patent portfolios points to the fact that there might be important strategic dimension to universities' behavior, that has so far been overlooked, and that needs further investigation.

Until today, the issue of under-commercialization of university patents has remained largely under-explored. However, with the patents being an important vehicle for the technology transfer, their underutilization may be a crucial issue to focus upon, both from an academic and policy standpoint. Considering the complexity of the patenting process, as well as the generally significant costs pertaining thereto (e.g. Colyvas et al., 2002), one would question why the inventions, which have been already patented, remain non-commercialized. Besides the evident problem of suboptimal use of budget resources and general inefficiency in the utilization of research results, one should also consider broader, long-term adverse effects that under-exploitation of patented research may have on the society at large. Thus, a significant share of university discoveries are in basic research and, therefore, they are more likely to have an impact on a whole range of subsequent “applied” research topics. This, in turn, may potentially block future research and alternative uses of innovations not only by other agents, but also by the respective patent owners themselves, which may not have the complementary assets or the incentives to invest in all the potential research directions being opened up by a broad patent (e.g. Merges and Nelson, 1990; Scotchmer, 1991; Verspagen, 2006), as may be in the case of university patents. Thus, the social cost of university patents remaining unused may be much higher, with the adverse effect of slowing down technological progress, especially if technologies are cumulative. In this manner, when universities fail to bring the patented inventions to the market, there is a danger that in the long run the open nature of the scientific process may be threatened, with the scientific progress being hampered to a significant extent (Verspagen, 2006).

The existing literature offers various explanations that might lie at the basis of a high level of nonuse of patented technologies, ranging from the commercial applicability of the underlying invention and value of a patent, to market-related inefficiencies (e.g. high transaction costs, suboptimal functioning of transfer mechanisms). The review of the existing studies, however, reveals that there is very scarce empirical and theoretical research that explicitly addresses the issue of commercial underutilization of patents, generated in academia. Due to the nature of public research institutes and universities, it seems obvious that we cannot fully use the rationale that is usually being applied to explain the nonuse of patents by corporate players. With that, as the recent evidence demonstrates, there may be more "strategic component" to the universities' behavior when it comes to managing their IPRs[1] than it has been generally considered (Giuri et al., 2007), so this could mean that the industry perspective could be, at least partially, applied to the research focused on universities and public research organizations.

Following this logic, our study highlights an underexplored area of academic research on the role of different types of knowledge – proxied for by formal and informal collaborations during the inventive process – for academic inventions and their effect on the subsequent success or failure of a patented invention to get commercially exploited. In particular, we argue that the type and nature of collaborations with external parties during the inventive process will determine the subsequent "destiny" of a resulting patent.

We build on the literature on the role of sources of knowledge and collaborations with external parties which took place during the inventive process. There is a well-established stream of research which points to the importance of interorganizational relationships for knowledge creation and generation of innovations (e.g. Schilling, 2002) and, more generally, the competitive performance of firms (e.g. Hipp, 2002; Santoro, 2000).

As we can see, the previous literature has extensively addressed the role of various types of collaborations of firms, but, to the best of our knowledge, no such attention has been given to the role of collaborations in the inventive process of a specific group of organizations which generate inventions: namely, universities and public research organizations. With that, universities represent an important category of participants to the innovation process, and understanding the factors that determine the utilization of patented inventions generated in academia will provide important implications for both academic researchers and practitioners. This issue becomes of even higher

[1] We use the terms "patents" and "intellectual property" interchangeably in this paper, although patents are only one type of intellectual property, along with trade secrets, trademarks, and copyrights (Rivette and Kline, 2000).

relevance due to the increased awareness of university's administration about the importance of patent valorization, as well as due to the rising social pressure from the state authorities for a more intensive technology transfer from academia to industry (Torrisi, 2013).

Our analysis shows that formal vs. informal interactions with various external parties, which took place during the inventive process, have a differing effect on the likelihood of patent's commercial exploitation. Thus, the role of formal collaborations with suppliers of the materials, tools and equipment result to reduce the likelihood of a patent to get commercialized. Instead of being commercialized, such patents will tend to be kept unused out of blocking considerations. In line with the previous findings of the research on the industrial firms, the knowledge received by the university from the customers – through both formal and informal interactions – will increase the likelihood of a patented invention to be used. The informal interactions with other universities will lead to a patent remaining sleeping in the university's patent portfolio, providing another evidence for the fact that purely academic inventions tend to be very basic in nature and quite distant from the industry needs, which explains the low interest for such patents from the market side and, as a result, an increased level of nonuse of such patents.

We proceed as follows. In section 2 we provide a reviews of the academic literature that addresses the issue of commercialization of patents - with the focus on academic patents - discussing in detail the main determinants of patent nonuse highlighted in the previous research. We then put forward a number of hypotheses concerning the effect of formal and informal interactions during the inventive process with various types of external parties on the likelihood of a patent remaining unused. Section 3 describes the methodology and data utilized, while section 4 reports the results of the econometric analysis. Section 5 concludes with the discussion of the findings and avenues for future research.

1. Theoretical background

1.1. Determinants of nonuse of academic patents

In this section, we briefly discuss the main factors, suggested in the existing literature, which might impede academic patents from getting commercialized and being instead kept unused in the university's patent portfolio.

One group of explanations for patent non-use offered in the literature points to **the intrinsic characteristics** of the patent and the underlying technology as the factor inhibiting the successful commercialization of the patented invention. Thus, the underlying technologies may be of small or no economic value, that leads to the lack of demand for them on the market (Gambardella et al., 2007). As the previous research shows, economically more valuable patents are more likely to be used due to their higher potential for profitability, and hence there will be a greater opportunity cost for keeping them unused (e.g. Shane, 2002; Palomeras, 2003).

The quality of patents generated in academia will be defined by several factors, or the combination thereof. One of the major issues discussed in the literature refers to the stage of development of an underlying technology. As the research shows, many university inventions tend to be very early stage (Thursby et al., 2001; Thursby and Thursby, 2007; Vohora et al., 2004). More specifically, their commercial potential is uncertain and it takes additional resources - in terms of time and money - to bring such inventions to the stage when they become commercially interesting for the venture capitalists or for the industry players to acquire patent rights for them. Due to higher risks and uncertainty in outcomes, industry may stay reluctant to license such inventions or to engage in co-development (Thursby et al., 2001; Chukumba and Jensen, 2005; 2007). In some cases, as the research shows, the embryonic nature of the academic inventions would even keep the companies from using the first option to acquire the patent generated from the sponsored research leading to the situation when the university is left "in an interesting position with a huge patent portfolio to exploit commercially" (Vohora et al., 2004).

According to another explanation for the situation when low-quality inventions get patented and then remain unused, universities may apply for patent protection for the technologies, which exhibit *a priori* low value, with the sole goal of "keeping up with the race". Thus, there is a stream of literature that argues about the negative effect of the Bayh-Dole Act and other legislative acts aimed at fostering university knowledge transfer in what regards the decrease in the quality of patents tending to be less important and less general than the patents issued before and after 1980 to U.S. universities with longer experience in patenting (Henderson and Trajtenberg, 1998; Mowery and Ziedonis, 2000; Mowery et al., 2006). In particular, it has been hypothesized that the increased pressure to patent faced by academic community has led to "hasty" patenting of inventions without performing pre-commercial research, which, in its turn, has resulted in accumulation of lower quality patents (Henderson and Trajtenberg, 1998; Czarnitzki et al., 2011).

Although later studies have demonstrated that such tendency, at least in the US, disappears over a longer time period (Mowery et al., 2002; Sampat et al., 2003; Verspagen, 2006), there may still be some negative effect of the perceived pressure to comply with the changing standards and performance indicators for academia, which will affect the rationale for patenting behavior among universities (Hall, 2005).

On the other side, *inside* the academia there has been as well registered a tendency for the changes in the evaluation standards and norms of professional behavior based not only on the traditional publication and research output metrics, but also on the performance in terms of number of patented inventions. This points to the presence of **the inventor-level determinants** which may affect – directly or indirectly - the rate of utilization of patents. Thus, some recent studies provide evidence about an increased pressure for the faculty members to patent - a situation which may lead to the accumulation of patents with lower quality and, thus, with lower potential value for the market (e.g. Czarnitzki et al., 2011). Just like in the situation when universities will "hurry" to patent the inventions to provide for the positive evaluation of their performance in terms of number of patents, individual researchers may, too, strive to increase their patenting activity through offering minor, low value, or "unready" inventions for patenting.

Another stream of literature has been highlighting the factors based on inefficiencies in the technology transfer process itself, such as, for instance, high transaction costs or the inefficiency in the management of technology transfer (Gambardella et al., 2007). In academia, the inefficient functioning of technology transfer processes has been usually explained by such **university-level characteristics** as the ineffective reward system for the managers of a university's technology transfer office (TTO) (e.g. Litan et al., 2008), or the differences in the goals and objectives, or simply the "styles" of negotiating, among various internal stakeholders (Agrawal, 2001; Dasgupta and David, 1994; Siegel et al., 2004; Siegel et al., 2004; Thursby and Thursby, 2003). As a result, the low efficiency of universities' TTOs will lead to a reduced number of patented inventions which will actually get commercialized.

Besides the factors which have been described above and which can be considered as "physiological" in that they have to do with the inherent characteristics of the patented invention, the individual inventor, or the local - university-level - context, the literature provides some, albeit rather limited, evidence on additional factors that may cause academic patents to remain unused.

As the growing stream of literature underlines, the increased embeddedness of universities in the national economic systems, as well as their stronger links and inter-dependencies with the industry and with other external stakeholders, may have defined a more complex and more competitive landscape in which to operate (Deiaco, Holmen and McKelvey, 2009; McKelvey, 2009). As such, an ever growing competitive "atmosphere" in which universities have to operate suggests that there may be **factors related to a broader institutional environment** in which universities operate that might affect the level at which commercial utilization of patented inventions takes place.

Innovation is a complex process in which various actors are involved. During the invention process, academic scientists interact with a broad set of external parties, among which are the suppliers of research equipment, tools and materials; customers in the form of industry firms or government structures; as well as other universities and research institutes. The existing literature provides some evidence on the role of different types of sources of knowledge on the commercialization rates of patented inventions (Gambardella et al., 2007); however, the role of collaborations of academic inventors with various external players during and after the inventive process has received limited attention in the academic literature. With that, as demonstrated by the recent studies on academic patents, informal collaborations among university scientists and industry firms constitute the majority of university-industry interactions, most often going “hand in hand” with the formal knowledge transfer (D’Este and Perkmann, 2010; Martinelli et al. 2008; Perkmann and Walsh, 2007), either in complementary manner, or having a “substitution” effect in that the knowledge embedded in the patent may be “going out of the back door” through informal, or non-IP based, interactions between the inventor and industry customer.

Based on the above considerations, in the following section we focus on reviewing the literature on the role of collaborations with external parties during the inventive process and we put forward the hypotheses regarding the effect of such collaborations on the likelihood of a resulting patent to get commercialized or to remain unused.

1.2. Interactions of universities with external parties and their effect on the patent nonuse

It is now widely recognized in the economic literature that the performance of national economies in terms of innovation and productivity is strongly influenced by the character and the intensity of the interactions between different elements of the national innovation systems (Nelson, 1993; Patel and Pavitt, 1994), and that novel and commercially useful knowledge is the result of collaboration and learning processes which take place among various participants to the innovation process, e.g. producers of innovation, users, suppliers, and public authorities (David and Foray, 1995). Since innovation and technological development depend increasingly on the ability to utilize new knowledge produced externally and to combine it with the stock of knowledge available in-house (Debackere and Veugelers, 2002), efficient knowledge transfer and the ability to learn through interactions with the holders of external knowledge have become crucial success factors in innovation process across different environments (Foray and Lundvall, 1996).

The literature on product innovation and technology management has acknowledged the role of external sources of technology in the successful development of new products and the critical role played by interorganizational relationships (Bidault et al., 1998; Willoughby, 1993). In particular, existing research places emphasis on empirical investigations of the impact of interorganizational cooperation on the performance of technology companies (Neill et al., 2001; Park et al., 2002) and on the role of organizations other than firms (e.g. universities) in such relationships (Santoro, 2000; Spencer, 2001).

As prior research suggests, there is a high rate of interorganizational collaborations that takes place along the stages of the innovation process, with various types of actors being involved therein. And as the research shows, collaborations with certain types of external parties tend to happen much more often in comparison with others. Thus, Fritsch and Lukas (2001) in their study of 1.800 German firms report that 33% of these firms had cooperated with research centres, while 60% had cooperated with customers, and 49% with suppliers and 31% with other firms, mainly competitors. Gemunden et al. (1992),exploring the sample of 800 German manufacturing companies, find that 21% had engaged in some type of R&D cooperation with other firms, while almost a third maintained some relationship with universities and research centres. While Chiesa and Manzini (1996) report that the firms in their sample reveal that as much as almost 70% of their collaboration is conducted with customers and suppliers. Knudsen (2007), investigating the extent of use of external relationships in collaborative product development and how these different types of interorganizational relationships contribute to successful new product development, finds that customers are involved in joint development efforts more frequently as compared to other types of external parties.

A number of other empirical studies have explored the determinants of R&D cooperation with certain types of external players (e.g. Tether, 2002; Belderbos et al., 2004) and have found substantial heterogeneity in the determinants to establish R&D collaborations depending on the type of a partner. As the evidence suggests, he choice of a particular type of partner for collaboration generally depends on whether that type of partner is considered an important source of knowledge for the innovation process (Belderbos et al., 2004).

In our study we consider both, the formal as well as informal interactions. The majority of studies within the last decade in the domain of management research on interorganizational relationships have focused much more strongly on the formal dimensions of the interactions rather than on the informal ones. However, there has been a stream of research underlining the possible notable role of informal interactions (Kogut and Zander, 1992; Von Hippel, 1987). Among more recent studies on the matter, the research by Willougby (2004) reveals that informal interactions have the greatest impact on the performance of the sample firms (biotechnology), and that a high level of formal collaboration appears to be efficacious mainly only as an adjunct to a high level of informal communication.

In the following sections we provide a more detailed account of the collaborations with each type of external parties, and we then put forward the respective hypotheses.

1.2.1. Interactions with suppliers

An increasingly large body of research on technology development describes the innovation process as taking place within a ‘network’ of actors (e.g. Hakansson, 1987), among which suppliers have an important place (Bidault et al., 1998).

The issue of supplier involvement started to be of a priority in the research agenda in the late 1980s; this happened after the Japanese scholars drew the attention of the academic community to the organization of product development projects in Japan (Bidault et al., 1998; Imai et al., 1986).

While the role of collaborations with the external parties in the innovation performance of industry companies has been well documented, few, if any, attempts have been made to study the external collaborations and their effect in relation to the universities and research organizations.

As the literature on industry collaborations argues, the knowledge received from suppliers could be crucial in the inventive process due to several reasons. In the innovation and product development literature, supplier involvement early in the development process combined with intense patterns of communication flows is viewed as driving forces for faster releases of new products and responses to competitor moves (Sobrero and Roberts, 2002). For instance, suppliers may contribute positively to product development performance by learning the features of the replaced component, subsequently using the achieved knowledge as a generator for new development projects (Knudsen, 2007). Besides, close collaboration with the supplier may create a solid base of cognitive resources common to the supplier and the user of the equipment, which will incentivize to continue the relation in the future.

These issues are found to be of particular relevance and importance for the industry companies that must constantly respond to various environmental pressures manifested in the technology mix and production complexity, industry structure, etc. (Bidault et al., 1998). As demonstrated by numerous studies on the matter, the close collaboration with the suppliers during the development process may lead to increased ability to face the external environment constraints and pressures, e.g. through considerable reduction in lead time, better crafted technological solutions, increased quality of the product, etc.

In the case of universities and public research organizations, the competition-based considerations may be of a less concern, due to the very nature of academic context; however, as mentioned earlier, with the external environment becoming more and more demanding in terms of procurement of funds and R&D output evaluation, universities are forced to apply more strategic approach towards the management of their resources. Following this logic, we may hypothesize that specific knowledge received through the interactions with suppliers will play an important role in the innovation process within academia and may influence the future commercial potential of the invention. The tools and equipment employed to carry out research may constitute a significant asset, and a competitive advantage, in the research efforts undertaken by a university. In this respect, the close and well-established collaborations with the suppliers may reduce considerably the risk of low quality or belated delivery of the research materials, which will enable to reduce the inventive cycle.

Besides, we would expect that the higher degree of informal, *tacit*, knowledge acquired from the suppliers during the informal interactions will lead to an increased probability of a patented invention to get commercialized, since such knowledge will be instrumental to crafting the research with the considerations of the market-related features which, in its turn, will tend to result in a patented invention more closely geared towards the market application. Our hypothesis will thus be the following:

Hypothesis 1: Collaborations with suppliers during the inventive process will decrease the likelihood of a patent to remain unused.

1.2.2. Interactions with customers

The prominent role of customers is consistent with a long-standing view in the innovation literature, where customers are viewed as the most important source of knowledge for invention processes. Thus, the SAPPHO project developed at SPRU in the 1970s pointed to fact that the ability to understand users' needs was the most important success factor in the production of innovations (Freeman and Soete, 1997), which is likely to apply to academic inventions, too (Giuri et al., 2007). As the literature highlights, the customers may contribute to the inventive process with highly market-oriented knowledge which can render the resulting invention commercially attractive and interesting for the target market (Gambardella et al. 2007; Knudsen, 2007).

In the particular case of universities and public research organizations, the customers are generally the industrial companies and firms, so, ceteris paribus, the better knowledge of the needs and requirements of the industry will increase the chances of a patented invention to find commercial application. The formal basis for such knowledge exchange during R&D collaboration between the university and the industry firm may come in the form of R&D partnerships, which include interactions over a prolonged period of time and may cover various related projects, or R&D contracts, targeting a specific research issue (Veugelers and Cassiman, 1999). We thus put forward the following hypothesis regarding the role of formally defined relationships between the university and its customers during the inventive process:

Hypothesis 2: Collaborations with customers during the inventive process will decrease the likelihood of a patent to remain unused.

1.2.3. Interactions with other universities

The role of universities and research centres in the firms' innovation process has been quite extensively covered in the existing literature (Laursen and Salter, 2004; Cohen et al., 2002). However, such studies provide the industry perspective, and little, if any, attention is given to the interactions that take place during the inventive activity among universities themselves. With that, this type of collaboration may be an important dimension to consider, especially in the light of the knowledge exchanged during such interactions.

As highlighted in the literature, one of the main factors that drive firms' collaboration with universities and research centres is the access to basic research (Bayona Saez et al., 2002; Cohen et al., 2002), so that universities and public research organizations are perceived as a crucial source of scientific knowledge which may be particularly instrumental for breakthrough innovations.

With what regards the applied research and the knowledge attached thereto, cooperation with universities in carrying out applied research has been historically developed to a much lesser extent (Mowery and Rosenberg, 1989); however, recently universities have been altering their approach and their whole mission, by carrying out more applied research which is much more closely geared to the needs of the industry (OECD, 1998; Santoro and Chakrabarti, 1999).

In the case of collaborations among universities, the literature has suggested that the nature and the extent of collaboration may as well depend on how basic or applied is the research (Katz and Martin, 1997). In particular, it has been argued that since applied research tends to be more interdisciplinary, the inventive effort may therefore require a wider range of skills than a single institution is likely to possess (Hagstrom, 1965). The university will thus enter in R&D partnerships with another university or research institute which possesses the knowledge, expertise and/or the equipment necessary to carry out a particular type of research. Such formal collaborative efforts will be likely to result in collaborative inventions which will then get patented. However, purely academic patents have been evidenced to be much less commercially exploited due to their fundamental and complex character, which, in many cases, will need further development efforts to be ready for market application (Giuri et al., 2007; Sampat et al, 2003; Rai and Eisenberg, 2003). We will thus expect that patents resulting from the formal collaborations with other universities and public research institutes will tend to remain unused. The related hypothesis will be as follows:

On the other hand, informal interactions may occur not necessarily with regard to the mutually conducted research project. In the spirit of "open" science and scientific collaboration among science fellows, the individual inventors from one university, working on a particular project for an industry company, may turn for help and expertise on certain issues to their counterparts from another university or research centre. Since in this particular case the inventor will make use of both – the market-related knowledge received from the industry customer, and the scientific expertise on certain aspects obtained through informal interactions with the colleagues from other universities, this will presumably increase the chances of a resulting patented invention to be successfully commercialized. Such contrasting forces, as the basic nature of the knowledge exchanged between the universities on the one hand and the possible value adding of informal interactions on the other hand, will lead to a neutral effect of this type of collaborations on the likelihood of a patent to remain unused:

Hypothesis 3: Collaborations with other universities during the inventive process will not have any significant effect on the likelihood of a patent to remain unused.

Having put forward the hypotheses we intend to test, in the following section we present the empirical part of our research, where we describe the data sources used, our sample, the variables and model utilized, as well as w outline the results of the regression analysis.

2. Methodology

2.1.Data sources and sample

The data for the present research come from the PatVal II survey which was carried out in 2010 and 2011 and was administered to the inventors of over 22,000 EPO patents with priority dates 2003-2005 employed in business firms, universities, PROs and other organizations across 20 European countries, Israel, USA and Japan.

The PatVal II survey addressed a broad set of questions on the inventors, the characteristics of the organization in which the patent was developed, as well as the invention process including information on the organizational context for the invention, the sources of knowledge used for the invention, several types of formal and informal collaborations and interactions occurred in the invention process, etc. Moreover, the survey asked about the reward for the invention, the value, and the commercialization routes of the patent. Information on the uses of the patent included the commercial use of the invention in internal production processes, patent licensing, patent sale and new firm formation.

For the purposes of our research, we focus on the sample of patents by the inventors affiliated with universities and public research institutes[2] at the time of the invention, which represent 1237 observations. We excluded observations with missing information on the variables we use in the analysis, after which our final sample amounted to **619** university patents.

2.2. Variables

2.2.1. Dependent variable

Our dependent variable is a dummy variable which we label NONUSE, equalling 1 if a patent has NOT been used either internally (in a product/process), or externally (sold, licensed, or used to found a spinoff) as reported by the inventor in the survey.

We further distinguish among various types of nonuse. We perform separate analyses for different categories of unused patents which we have identified based on the additional information reported by the inventors, e.g. with regard to the willingness of using a patent in the future, or whether blocking was reported as a reason for patenting. In this manner we distinguish between patents remaining unused out of blocking considerations (NONUSE_BLOCK), and patents reported as unwilling to use in the future (NONUSE_NOWILL), and, lastly, all the remaining patents reported as unused which we label as "sleeping" patents (NONUSE_SLEEP) (Giuri et al., 2007).

2.2.2. Explanatory variables

In line with the hypotheses put forward in the previous section, we construct the following explanatory variables.

Collaborations with external parties

[2] For the simplicity, hereinafter we use the word "universities" to collectively refer to universities and public research institutes.

The indicators of collaborations with external parties were derived from a series of survey questions about the university's informal communication and formal collaboration during the inventive process that led to the patented invention with various types of external parties: customers (CUST), suppliers (SUPP), and other universities (UNIV).

For each case we thus introduce a respective dichotomous variable that equals 1 if such informal or formal collaboration took place, and 0 otherwise.

2.2.3. Control variables

We include a set of variables that may have an influence on the patent nonuse by universities.

At the patent level we control for several issues. First, we control for *the economic value of the patent* (PAT_VALUE) as compared to other patents in the inventor's industry, as reported by the inventor. As several studies show, patents that remain unused have, on average, lower perceived economic value as compared to commercialized patents (e.g., Gambardella et al., 2007).

At the level of a patent we also control for *the nature of the underlying invention* (ORIGIN). As the previous evidence shows, the inventions which are not the results of the targeted research effort will tend, as a rule, to remain unused due to the lack of commercial value, absence of demand, or just because of the failure of TTO staff to recognize the market potential of such unintended discoveries due to the time and resource constraints (e.g. Gambardella et al., 2007).

Then, we also take into account *the technological field* of the patented invention (TECHFIELD). It has been evidenced that the high percentage of unused patents results to be in biotechnology, pharmaceuticals/cosmetics and motors industries, with blocking patents being more frequent in petrochemicals, organic chemicals and motors (Torrisi, 2013). Moreover, effectiveness of patents in protecting inventions may be a factor affecting the rate of strategic patenting, so that higher patent effectiveness will result in a greater level of strategic patenting. Since the patent effectiveness differs for each industry, we introduce technology dummies represented by 5 OST macro sectors to control for the industry effect.

At the individual level, we control for *individual inventors' characteristics*, such as age (INVENTOR'S AGE), education (EDUC), gender (GENDER) (equal 1 if female, and 0 if male), and, finally, experience for which we proxy with the number of scientific publications (PUBLICATIONS) and patents held by the individual (PATENT STOCK).

2.3.Empirical approach

Taking into consideration the binary nature of the dependent variable, we employ a probit model to explore the effect of our explanatory variables on the likelihood of a patent to remain unused. We compute the marginal effects of the explanatory variables in the univariate probit models for all four outcomes to see how much the (conditional) probability of the outcome variable changes when we change the value of a regressor while holding all other regressors constant at their mean values.

3. Results

In Table 3 we present the marginal effects of the probit estimations for each of the specified cases of patent nonuse, namely: general nonuse, nonuse with no intention to use a patent in the future, nonuse out of blocking considerations, and sleeping unused patents. The model, which results are reported in the table, includes all the covariates and control variables included in the analysis, i.e. the full model.

As it can be seen from the table, the signs of several control variables are statistically significant with regard to the probability of a patent to remain unused. Thus, at the individual level, inventor's age has a negative and significant association with a patent remaining unused in general and sleeping, which is in line with the argument on the generally positive role of inventor's experience on the likelihood of commercial exploitation of the patents. This applies also to the patent stock, which, according to the results, has a negative association with the patents reported as not willing to use in the future; in other words, the previous experience of the inventor increases the likelihood of a patent, even if not yet commercialized, to be considered for commercialization in the future.

A high level of inventor's education shows a negative correlation with the probability of a patent to remain sleeping. Gender, and more specifically, being a female, has a positive and significant effect on the likelihood of a patent to remain unused in general, and out of blocking considerations, the latter being quite a surprising result which would need further exploration.

The quality of a patent, which we measure as the economic value reported by the inventors, provides quite expected effects on different cases of patent nonuse. Thus, low-quality patents (last category, bottom 50) have a significant positive effect on the likelihood that a patent will remain generally unused ($p<0.1$), unused with no intention to use in the future (at $p<.001$), or will remain sleeping ($p<.05$). "Quality patents", (top25 and top50) are less likely to remain unused out of blocking considerations.

As for the key explanatory variables, according to our hypotheses, we look separately at the informal/formal collaborations between inventor's university/research institute of affiliation and suppliers, customers and other universities which took place during the invention process.

In case of collaborations with customers, as expected and in line with the existing literature, there is a negative and significant effect in all cases except for nonuse out of blocking considerations.

The collaborations with suppliers show a significant positive effect on the probability that a patent will remain unused out of blocking considerations. This may be explained by the fact that, as mentioned earlier, with the external environment becoming more and more demanding in terms of procurement of funds and R&D output evaluation, universities are forced to apply more strategic approach towards the management of their resources. This, in turn, may point to a situation in which specific knowledge received through the interactions with suppliers plays an important role in the innovation process within academia and may influence the future commercial potential of the invention. The tools and equipment employed to carry out research may constitute a significant asset, and a competitive advantage, in the research efforts undertaken by a university. In this respect, the close and well-established collaborations with the suppliers may reduce considerably the risk of low quality or belated delivery of the research materials, which will enable to reduce the inventive cycle.

To sum up, as the results of the regression analysis show, collaborations with suppliers increase the likelihood of a patent to be kept unused out of blocking considerations, while a patent is more likely to get commercialized when collaborations with customers took place during the inventive process. The interactions with the customers result to be important for the considerations of future use of a patent that currently remains unused. This points to the fact that such "willing to use" patents embedding customer-related knowledge may fail to get commercialized straight away due to not the lack of commercial potential – as evaluated by the universities themselves – but rather to the inefficiencies in technology transfer markets, high transaction costs, etc.

The absence of significant effect in the case of collaborations with universities supports our hypothesis on the "neutral" effect of two contrasting forces: basic nature of the knowledge which is exchanged during the universities which will lead to lower chances of commercialization (Giuri et al., 2007), while the informal interactions with the academic peers in the spirit of open science may bring important and valuable knowledge which will heighten the chances of a patent to get commercialized.

4. Discussion and conclusions

The findings of the present research regarding the effect of interactions with suppliers on the likelihood of a patent to remain unused out of blocking considerations provide important policy implications.

As the results of our study reveal, the patents that embed knowledge received from suppliers at the invention stage will tend to be kept unused and reported as blocking; this may be due to the fact that the suppliers may utilize the information embedded in such patents in future inventions. In this case, a patent becomes a strategic blocking tool for defensive purposes. As the literature suggests, technology blocking can occur when a particular patent isbroad enough to endow its holder with the power to control further developments related to the invention protected by a patent (Guellec et al., 2008). These may include improvements on the invention, particular applications, or other inventions relying on similar principles. The area of genetic materials represents one of the examples of such technology blocking patents.

The same logic may also apply to future projects which the university itself is planning to carry out based on the patented invention and planning to rely on the same supplier. This latter consideration is in line with the issue which has been widely discussed in the practitioners' literature and which regards patenting of the so-called research tools. The US legislation, for example, draws no distinction between downstream inventions that lead directly to commercial products, and fundamental research discoveries that broadly enable further scientific investigation, among which research tool patents may be included. Taking this opportunity, universities tend to file patent applications on basic research discoveries, such as new DNA sequences, protein structures, and disease pathways, that are primarily valuable as inputs into further research, thereby violating one of the main principles of the open science. As evidenced in the literature on the matter, even when they do not seek patents, universities often try to preserve their expectations for profitable payoffs by imposing restrictions on the dissemination of research materials and reagents that might generate commercial value in subsequent research (Rai and Eisenberg, 2003).

In the case of a patented invention, the issue of access to research tools relates to the ability of a patent holder to exclude others from using the material. As such, if, for instance, a single patent holder has a proprietary position on a large number of nucleic acids, they may be in a position to "hold hostage" future research and development efforts by either intentionally or unintentionally not realizing the potential of the patented research tool (Clark et al., 2000).

The patenting of university inventions and related conflicts of interest might have negative influences on these norms; slow the diffusion of university inventions, including research tools; and stifle innovation (Eisenberg, 1989; Heller and Eisenberg, 1998). As it has been noted before, the institutional arrangements, within which TTOs are embedded, have encouraged some of such university TTOs to put pressure on revenue maximization rather than on facilitating knowledge dissemination for the good of the entire society (Kenney and Patton, 2009).

All this poses serious concerns about the true effect of the Bayh-Dole Act and similar pieces of legislation in other countries with regard to its role as a mechanism to foster commercialization of academic research. This leads to important policy implications, since there is a high risk that patents on basic research – as in case of most patents generated in academia – can considerably impede future inventive activities, especially in the fields where innovation is cumulative (e.g. biomedicine, semiconductors) (Scotchmer, 1991; Merges and Nelson, 1990). Until recently, most of the discussions on the proper use of various forms of IP protection in general, and patents in particular, have been dominated by models that apply a linear approach to the process of scientific discovery and innovation; however, today many fields (e.g. biomedical research, semiconductors) are characterized by a high multidisciplinary complexity which leads to new models of innovation and research being considerably inter-related, and which points out the importance of considering how patent rights are being used (Long, 2000).

The present study has only "scratched" the surface and further research on the effect of various types of interactions between academic inventors and external stakeholders on the rate of commercial exploitation of academic patents will be needed.

Future research should also take into consideration additional, potentially intervening, factors which could be included in the model as explanatory or control variables. Among the major ones are the university-level characteristics which, according to the literature, could influence the rate at which university patents get commercialized (e.g. university’s size, R&D budget, the equality of a technology transfer office, and others).

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ANNEX

Table 1. DEFINITION AND MEASURES OF VARIABLES

Dependent variables

NONUSE	Dichotomous variable equal to 1 if the patent was not used commercially and 0 if yes
NONUSE_NOWILL	Dichotomous variable equal to 1 if the patent was not used and the owner was not willing to use the patent in the future; 0 if yes
NONUSE_BLOCK	Dichotomous variable equal to 1 if the patent was not used and blocking was reported as the main reason, and 0 otherwise
NONUSE_SLEEP	Dichotomous variable equal to 1 if the patent was not used and blocking was NOT reported as the main reason for nonuse; 0 if otherwise

Covariates and Controls

SUPP	Dichotomous variable equal 1 if there were formal or informal interactions between an inventor's employer and SUPPLIERS during the invention process; 0 if otherwise
CUST	Dichotomous variable equal 1 if there were formal or informal interactions between an inventor's employer and CUSTOMERS during the invention process; 0 if otherwise
UNIV	Dichotomous variable equal 1 if there were formal or informal interactions between an inventor's employer and UNIVERSITIES during the invention process; 0 if otherwise
ORIGIN	1- the invention was the targeted achievement of a research or development project (baseline); 2 – the invention was an expected by-product of a research or development project; 3 -the invention was an unexpected by-product of a research or development project; 4 - the idea for the invention was directly related to the inventor' normal job (which is not inventing), and was then further developed in a (research or development) project; 5 - the idea for the invention came from the inventor' normal job (which is not inventing), and was not further developed in a (research or development) project, that is the idea was patented without further research or development costs; 6 - the idea for the invention came from pure inspiration/creativity, and was not further developed in a (research or development) project
PATVALUE	Dummy variables for perceived economic value of a patent in comparison with other patents in the inventor's industry, as reported by the inventor: 1) top10 if the patent is rated amongst the top 10% most valuable patents in the technological field (baseline case); 2) top25 if it is rated in the top 25%, but not in the top 10%; 3) perceived patent value top50 if it is rated in the top 50%, but not in the top 25%; 4) perceived patent value bottom50 if it is rated in the bottom 50%
EDUC	An aggregate variable showing the level of inventor's education with: EDUC_SCHOOL - high school or lower (baseline case); EDUC_TERT –

	tertiary education; EDUC_PHD – PhD education
GENDER	Dichotomous variable equal 1 if the inventor's gender is female, and 0 if it is male
INVENTOR'S AGE	Logarithm of age of the inventor at the time of the invention
PATENT STOCK	Logarithm of number of inventions that the inventor has made so far (it may also include inventions that were not patented)
PUBLICATIONS	Logarithm of number of articles published in scientific journals
TECHFIELD	Six ISI INPI OST Macro Technological Classes: (1) Electrical engineering (baseline case); (2) Instruments; (3) Chemistry&Pharmaceuticals (4) Process engineering; (5) Mechanical engineering; (6) Consumer goods/Construction technologies

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Nonuse	619	.529	.499	0	1
Nonuse_nowill	619	.145	.352	0	1
Nonuse_block	619	.158	.365	0	1
Nonuse_sleep	619	.371	.483	0	1
Supp	619	.192	.394	0	1
Cust	619	.200	.400	0	1
Univ	619	.397	.489	0	1
Gender	619	.090	.287	0	1
Inventor's age	619	3.790	.259	2.995	4.406
Patent stock	619	2.265	1.26	0	7.600
Publications	619	3.647	1.502	0	7.378

Table 3. Marginal effects of probit estimations

Variable	nonuse	nonuse_nowill	nonuse_block	nonuse_sleep
Origin2	0.067	-0.003	-0.022	0.095
	(0.067)	(0.04)	(0.041)	(0.066)
Origin3	-0.014	-0.023	-0.082***	0.087
	(0.056)	(0.032)	(0.031)	(0.055)
Origin4	-0.064	-0.064**	-0.047	-0.003
	(0.068)	(0.031)	(0.04)	(0.067)
Origin5	-0.106	-0.076*	-0.077	-0.012
	(0.11)	(0.041)	(0.055)	(0.11)
Origin6	0.054	0.019	0.008	0.057
	(0.072)	(0.047)	(0.051)	(0.072)
Educ_Tert	-0.211	0.006	0.069	-0.222*
	(0.146)	(0.09)	(0.142)	(0.116)
Educ_PhD	-0.184	-0.009	0.081	-0.260*
	(0.145)	(0.092)	(0.095)	(0.148)
Gender	0.140*	-0.006	0.118*	0.024
	(0.072)	(0.04)	(0.062)	(0.073)
Instruments	-0.112	-0.070**	-0.089**	-0.001
	(0.069)	(0.034)	(0.035)	(0.065)
Chemistry	-0.129**	-0.029	-0.082**	-0.028
	(0.065)	(0.037)	(0.039)	(0.062)
Process	-0.109	-0.112***	-0.067	-0.011
	(0.087)	(0.023)	(0.043)	(0.085)
Mechanical	0.111	-0.001	-0.066	0.204*
	(0.105)	(0.065)	(0.054)	(0.108)
Construction	-0.169	-0.077*	-0.103**	-0.04
	(0.131)	(0.046)	(0.04)	(0.127)
top25	-0.018	-0.006	-0.082**	0.086
	(0.063)	(0.041)	(0.035)	(0.064)
top50	-0.07	-0.014	-0.090***	0.041
	(0.066)	(0.041)	(0.034)	(0.067)
bottom50	0.105*	0.162***	-0.034	0.142**
	(0.062)	(0.052)	(0.038)	(0.065)
Inventor's age	-0.162*	-0.027	0.033	-0.200**
	(0.098)	(0.059)	(0.059)	(0.093)
Patent stock	-0.017	-0.024**	-0.015	-0.002
	(0.019)	(0.011)	(0.013)	(0.018)
Publications	0.031	-0.013	0.007	0.025
	(0.02)	(0.013)	(0.013)	(0.02)
Suppliers	0.012	0.007	0.086**	-0.078
	(0.057)	(0.038)	(0.043)	(0.052)
Customers	-0.165***	-0.070**	-0.016	-0.142***
	(0.055)	(0.028)	(0.037)	(0.049)
Universities	0.019	0.011	-0.043	0.063

	(0.044)	(0.027)	(0.029)	(0.043)
N	619	619	619	619

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11
1. nonuse	1.00										
2. nonuse_nowill	0.39*	1.00									
3. nonuse_block	0.41*	0.19*	1.00								
4. nonuse_sleep	0.73*	0.26*	-0.34*	1.00							
5. Suppliers	-0.03	-0.03	0.06	-0.08	1.00						
6. Customers	-0.13*	-0.09*	-0.01*	-0.13	0.29*	1.00					
7. Universities	0.03	0.01	-0.05	0.06	0.17*	0.07	1.00				
8. Gender	0.07	0.05	0.08*	0.01	0.02	-0.00	0.01	1.00			
9. Inventor's age	-0.05	-0.08	0.03	-0.08	0.03	0.05	0.01	-0.14	1.00		
10. Patent stock	-0.05	-0.12*	-0.03	-0.03	0.01	0.05	0.02	-0.25*	0.29*	1.00	
11. Publications	0.02	-0.08	0.02	0.01	0.02	-0.07	0.16*	-0.12*	0.51*	0.42 *	1.00

Note: * <0.5

The Effect of University-Level Support Policies on Female Participation in Academic Patenting

The Effect of University-Level Support Policies on Female Participation in Academic Patenting

Abstract

A growing stream of academic literature investigates various factors which impede the participation of women in patenting and commercialization of the patented research; however, limited research has been performed on the ways to address this gender gap. We explore whether the institutional ownership arrangements of university patent, as well as the presence of such university-level support measures as a technology transfer office (TTO) and IP policy has a positive effect on the female involvement in patenting. We test our hypotheses on a sample of 2538 academic patents produced by Italian inventors in the period of 1996-2007. The results of our research highlight a positive role of a university in addressing the gender gap in productivity and in commercial engagement within academia.

Keywords: University-Level Support Policies, Female Patenting, Participation of Women in Patenting, Female Academics

1. Introduction

With the interaction between science and the economy becoming more significant as the basis of sustained economic development, women's growing presence in the science and technology transfer fields in academia makes them important players in the innovation process. Therefore equal participation to the production and diffusion of scientific knowledge has emerged as a major political, economic, and social issue, which calls for research explicitly addressing gender dynamics. Under such circumstances, the issue of under-performance of women and their under-representation in the sectors of high technological impact – e.g. universities, academic research centers, etc. - poses a serious problem for both academic researchers and policy makers.

As underlined by several authors in the recent literature on the matter, current attempts to promote scientific excellence in various countries across the world "can no longer ignore the gender aspects of research organizations, managers, programs, policies and outcomes" (Ranga & Etzkowitz, 2010). Several other studies have further urged that gender-specified metrics and more inclusive analytical perspectives must be applied in order to assess the overall science and technology workforce situation and to introduce related policy decisions and investments in human capital (e.g., McNeely & Schintler, 2010).

For what concerns technology transfer activities from universities to the industry, the ongoing research shows that there exists a clear gender gap at virtually every stage of the innovation process: women are less likely to disclose inventions than men are, they are less likely to patent, and less likely to engage in entrepreneurial activity, such as starting a company or serving on a scientific advisory board (Ding, Murray, & Stuart, 2006; Ding, Stuart, & Murray, 2012; Giuri et al., 2007; Frietsch, Haller, Funken-Vrohlings, & Gruppa, 2009; Stephan & El-Ganainy, 2007; Technopolis, 2008). The findings from such a wide range of academic and industry studies provide solid evidence that women represent a considerable unexploited source of human capital in Europe, and that their contribution to Europe's potential is not being maximized.

There is a growing stream of academic literature that investigates various factors which impede the participation of women in patenting and commercialization of the patented research (Ding et al., 2006, 2012; Hunt, Garant, Herman, & Munroe, 2012; Murray & Graham, 2007; Tartari & Salter, 2012; Whittington & Smith-Doerr, 2005, 2008). However, to the best of our knowledge, limited research has been performed in what regards the ways to address this gender gap by analyzing the specific measures and policies that could be put in place to foster broader participation of women academics in all stages of commercial exploitation of an invention.

In order to address this gap, we focus on the factors that might facilitate the female involvement in academic patenting. In particular, we explore whether and how the universities and their internal policies and support structures may create a more favourable and engaging environment for women scientists and foster their broader participation in patenting activities. In line with this objective, we first investigate whether the institutional ownership arrangements of university patent affects the level of female participation in patenting, distinguishing between university-owned and university-invented academic patents (Geuna & Nesta 2006; Lissoni, 2012; Lissoni, Pezzoni, Poti, & Romagnosi, 2013). In the former case, patented inventions generated by publicly funded research are owned by the university that employs the academic inventor. In the latter case, ownership of patents generated by academic inventors remains with these inventors, or a corporation or organization with which they associate, not the university itself. In this respect, we hypothesize a positive effect of university ownership on the share of women academics engaging in patenting activities.

In the second part of our analysis, we investigate the role of university-level mechanisms in support of patenting and knowledge transfer, namely TTO offices and IPR regulations, to see if they facilitate a broader participation of female academics in patenting. We hypothesize that women academic scientists will be more “responsive” than their male counterparts to the presence of such internal structures and regulations that facilitate the participation in patenting and commercialization activities. Such internal support mechanisms may reduce the bias against women, address the high levels of ambiguity in the patenting process, as well as provide legitimacy and visibility to women scientists which they often lack in the traditionally male-dominated working environments as that of academia (Murray & Graham, 2007; Roos & Gatta, 2009; Rosser, 2009; Stephan & El-Ganainy, 2007). Taking into consideration all of the above said, we hypothesize that there will be more patents with female participation at the universities which have an established TTO, as well as those which have adopted explicit IP regulations to govern the IP-related matters, in comparison with the universities that lack such internal support mechanisms.

We test our hypotheses on a sample of 2538 academic patents produced by Italian inventors in the period of 1996-2007, including 504 university-owned and 2034 university-invented patents. In line with the existing studies (Mauleon & Bordons, 2009; Naldi, Luzi, Valente, & Vannini Parenti, 2004), we measure female participation in patenting by looking whether there was at least one female academic inventor reported on the patent team.

We thus aim to provide a value added in the research on women participation in patenting by conducting an in-depth study of a particular national context with a longitudinal approach. Our contribution is thus to the general literature on the gender gap in science and technology, as well as to the more specific debate on the role of institutional context and, specifically, of various university-level policies and support elements in fostering broader participation of women at different stages of the innovation process.

Therest of the paper presents first a review of the relevant literature, then describes the context of the study, the sources of data, sample and the methods employed. It then presents the results of the regression analyses, and, in conclusion, it discusses the policy implications of our findings.

2. Theoretical background

2.1. The gender gap in academic patenting

Even though the number of women academics has significantly grown in recent decades, their involvement in patenting and other forms of knowledge transfer remains quite limited (Murray & Graham, 2007; Rosa & Dawson, 2006; Thursby & Thursby, 2005; Whittington & Smith-Doerr, 2005). Moreover, the positive developments registered by academic women in their institutional status, individual rank or scientific productivity are not equally reflected in their involvement in patenting and commercialization of their research through such technology transfer activities as, for example, licensing or creating spin-offs (Murray & Graham, 2007). As the results of existing studies demonstrate, women faculty engage in patenting at a decreased rate than male scientists (Morgan, Kruytbosch, & Kannankutty, 2001; Whittington & Smith-Doerr, 2005, 2008; Whittington, 2007); they do not sit on scientific advisory boards at the same rate as men scientists do, as well as they make up a much smaller percentage of company founders (Ding, et al., 2006, 2012; Stuart & Ding, 2006; Murray & Graham, 2007).

Previous studies highlight several types of factors that may prevent women academics from engaging in patenting and technology transfer more actively. One of the most widely cited factors is the limited access to different types of resources, e.g. financial, human or those of social capital (Mosey & Wright, 2008; Rosa & Dawson, 2006; Stephan & El-Ganainy, 2007). Moreover, the previous research distinguishes the factors which are related to the social construction of gender and the stereotypes pertaining thereto manifested in the traditional gender roles which assign to a woman more household chores (Etzkowitz, Kemelgor, & Uzzi, 2000) and lead to the conflict between family life and work (Shaw & Cassell, 2007). These may impact on the women's decision to engage in "extra" activities like, in this case, those of technology transfer. Other arguments rely on the gender profiles that present women as having greater risk aversion, a lower level of interest in money and financial transactions, or different attitudes to competition (Niederle & Vesterlund, 2005; Stephan & El-Ganainy, 2007).

The above classification falls in line with the sociological perspective which offers two groups of explanations to why women, in comparison with their male counterparts, tend to be less productive, and, in this particular case, why they engage to a much lesser extent in different forms of academic activities, starting from publishing, and most recently licensing, founding academic start-ups and other forms of technology transfer. According to the dispositional approach (sometimes referred to as the "difference model") female scientists tend to lag behind their male colleagues along various professional dimensions because the two genders are "different" in their values and priorities, which lead to different choices and work-related decisions (Sonnert & Holton, 1995). However, there is evidence from a number of studies performed in several professional environments (e.g. entrepreneurship), which demonstrates that women are not that different in their motivations and preferences once such individual-level characteristics as education, professional experience, income etc. are controlled for (e.g., Brush, Carter, Gatewood, Greene, & Hart, 2001). This points to the arguably higher explanatory power of the second, structural, approach to gender gap in professional attainments.

The structural approach (the so-called "deficit model") argues on the other hand that female scientists are less productive and less involved in commercial activities than male scientists because they have fewer opportunities than men throughout the course of their careers. In other words, there are legal, political, and social structural obstacles that hinder female scientists from attaining the level of career success that male scientists are more likely to achieve (Corley & Gaughan, 2005; Long, 2001).

When looking at a specific context of science, the structural perspective reaffirms the importance of structural sources of gender inequality in science. In particular, researchers adhering to this perspective argue that women and men scientists demonstrate different productivity and engagement levels due to the fact that they are located in different structural positions which results in different access to valuable resources (e.g., Xie & Shauman, 1998; Whittington & Smith-Doerr, 2005). Thus, in relation to research productivity, some authors find a very limited direct effect of gender once structural characteristics are controlled for and the differences in the distribution of resources such as space, equipment, and time are taken into account (Xie & Shauman, 1998, 2004). The previous research has also found that women academics tend to experience less mentoring and collaboration opportunities during their scientific career (Long & McGinnis, 1985), which, coupled with their argued higher awareness of and sensitivity to the presence of organizational constraints (Fox & Ferri, 1992), largely contribute to their lower involvement in a wide range of job-related activities.

Much of the early research on academia failed to consider how resource distribution and the structure of academic work is gendered (Whittington, 2009). With that, organizational context may likely play an important role in gender equality, as successful scientific work relies on equal access to facilities and funds, available help, and a supportive research environment (Fox 1991, 2001).Based on the previous arguments, the role of the university – as an employer organization - becomes an important issue to consider in the debate on the ways of increasing female participation in the innovation processes. As so much as the policies and measures implemented at the university level may result highly instrumental in addressing the gender gap in academic patenting. In the following section we thus turn to the literature on the general role of university-level measures and structures in support of knowledge transfer, as well as we explain in detail the rationale behind the assumption on the positive impact of such measures on the female participation in patenting activities.

2.2. The role of university-level support mechanisms in addressing the gender gap in academic patenting

University setting has been traditionally characterized by a high degree of complexity due to multiple outputs, ambiguous goals, and stakeholders with differing interests (March & Olsen, 1976), and so the role of various mechanisms and policies in support of patenting and knowledge transfer that are designed and implemented at the university level cannot be overestimated.

There exists an extensive body of research on the role and effect of such internal support structures as a TTO (Louis, Jones, Anderson, Blumenthal, & Campbell, 2001; Thursby et al., 2001) or internal policy regulations on patenting or the creation of spinoffs (Baldini, Grimaldi, & Sobrero 2007; Giuri, 2Munari, & Pasquini, 2013; Lissoni et al., 2013). These studies highlight the importance of TTOs and university policies for successful transfer of academic knowledge to the market place. In particular, the literature argues that through thecreation of TTOs and the adoption of internal patent policies, universities can mitigate market inefficiencies,which arise with regard to patenting and commercialization of academic inventions (e.g. information asymmetries, high embedded risk, etc.). However, in addition to being important signalling mechanisms for external third parties and shareholders (Baldini, Fini, Grimaldi, & Sobrero, 2010), such internal policies and mechanisms are designed with the goal of addressing the needs of the internal parties - i.e. academic inventors -by providing professional support and assistance in commercializing their research. In particular, as suggested by the findings of the qualitative studies on the gender gap in academia (e.g. Ding et al., 2006, 2012; Murray & Graham, 2007), these university internal policies and structures may be more instrumental to a particular group of academic inventors, i.e. women scientists.

The existing research offers several explanations for why this may be the case. For instance, the study by Ding et al. (2006) shows that one of the major hurdles for women academics in relation to their commercial engagement is the lack of exposure to the commercial sector. Most women academic scientists tend to have few contacts with industry since they find it harder than men to make such industry contacts (Ding et al., 2006). This may suggest that the role of different support mechanisms inside the university may play a crucial role in increasing women scientists' participation. It has been found that, lacking industry connections, women find it time-consuming to explore whether an idea is commercially relevant. In contrast, men often describe an industry contact as a "precursor" to patenting. As reported in the interviews, many female faculty members felt deterred from completing a patent filing due to being hampered by their narrow networks and being concerned about the time it would take to "shop" a patent around (Murray & Graham, 2007).

One of the factors reducing the perceived cost of patenting for women is represented by formal institutional sponsorship. In the qualitative part of the study by Ding et al. (2006), many women commented that their TTO provided industry contacts, advice, and encouragement to develop the commercial aspects of their research. In a parallel study by the colleagues, the findings showed the decline of gender differences among junior faculty prompted by the presence of institutional support (e.g., TTOs) (Murray & Graham, 2007).

Another aspect which can make institutional factors more salient for women scientists than for men has to do with the concern expressed by many female faculty members that pursuing commercial opportunities might hinder their university careers. The women academics who were interviewed in the study by Ding et al. (2006) were found to be more likely to describe the challenges associated with balancing multiple career elements: teaching, research, and commercialization. Unlike their male counterparts, who describe their patenting decisions as unproblematic and driven by "translational" interests, female faculty express concern about the potentially negative impact that patenting might have on education, collegiality, and research quality (Ding et al., 2006).

The institutional support mechanisms may address the above mentioned issues by reducing the ambiguity in the perception of patenting and other knowledge transfer activities by women faculty through providing explicit information on the process of commercialization, as well as offering additional support and guidance and facilitating access to financial resources and industry networks. Based on the theoretical considerations described above, in the following section we put forward the hypotheses related to the effect of university ownership of academic patents (distinguishing between university-owned and university-invented patents) and two types of internal support mechanisms, namely a university technology transfer office (TTO) and the internal IP regulation, on the level of female academics' participation in patenting.

3. Hypotheses

3.1. The role of university ownership of patents

A series of legislative reforms implemented around the world, starting with the Bayh-Dole Act in the United States, aimed to strengthen the assignment of patent ownership rights to universities so that to encourage transfers of university research to industry settings (Geuna & Rossi, 2011; Grimaldi, Kenney, Siegel, & Wright, 2011). Such reforms in support of institutional ownership of academic patents sought to provide adequate incentives for universities and PROs to develop technology transfer capabilities and invest in patenting and commercialization structures, because they enjoyed greater ownership certainty (Geuna & Rossi, 2011). Extant literature analyzes legislative changes governing university IPR ownership in different countries (Lissoni et al., 2013; Mowery & Ziedonis, 2002), the distribution of academic scientists' patenting activity in various countries (Baldini et al., 2006; Lissoni, Llerena, McKelvey, Sanditov, 2007), the factors that might explain the assignment of academic patents to universities rather than corporations or other applicants (Markman, Gianiodis, & Phan, 2008; Thursby, Fuller, & Thursby, 2009), and the effect on commercialization rates (Crespi et al., 2010; Giuri et al., 2013). However, so far no direct attempt has been made in the literature in order to assess the involvement of women academic inventors in university-owned patents, as compared to university-invented ones.

As to this point, based on the above mentioned arguments, one should expect that university IPR ownership should favour a stronger participation of women researchers in patenting activity. Institutional ownership represents a fundamental prerequisite to allow universities and PROs to create technology transfer offices (TTOs) that centralize, professionally manage, and strengthen technology transfer procedures. This step appears instrumental for fostering technology transfer activities in that professors and researchers often lack the expertise, business knowledge, commercial relationships, financial resources, or interest to engage in commercialization. As explained in the previous section, this gap is particularly pronounced for women academic inventors, who could therefore enjoy a greater benefit from the support of such infrastructures and policies.

In addition to that, the existing evidence shows that the participation, as well as the contribution of women in the patenting arena, tends to increase with the number of co-inventors cited on the patent team, which could indicate a better inclination of women to co-operate and to participate in large research groups (Mauleon & Bordons, 2009; Naldi et al., 2004). It has been evidenced that universities and research institutions, according to the results of a large-scale study carried out in 6 major European countries, tend to have a larger share of collaborative patents as compared to firms (Giuri et al., 2007). This difference may be due to the differing nature and goals of these two types of organizations. Thus, firms by definition are more competition-oriented and, thus, tend to internalize as much as possible the inventive process in order to avoid leakages of proprietary information; while universities, taking into consideration their traditional mission of knowledge diffusion, will be more open to collaborative research efforts, which will ultimately result in a larger percentage of collaborative patented inventions owned by the universities. Following this line of reasoning, university-owned patents should be associated with more collaborative inventive activity, and by that enhance the involvement of women researchers in the team.

Based on the above arguments, we hypothesize that there will be a higher likelihood of academic female participation among university-owned patents as compared to university-invented ones.

Hypothesis 1: University-owned patents have a higher likelihood to have at least one female academic inventor in the patent team, as compared to university-invented patents.

3.2. The role of TTO on women patenting

The institutional ownership, generally, points to the establishment of an active technology transfer office (TTO), which operates as the support mechanism for smoother transition of research from academia to industry. There is an extant stream of literature dedicated to exploring the role of a university's TTO as a mediating institution for improving the link between universities and industry (Markman, Gianiodis, Phan, & Balkin, 2005; Phan & Siegel, 2006; Siegel, Waldman, & Link, 2003). Technology transfer offices act as "brokers" between academia and industry by providing expertise and managing commercialization processes related to patenting, licensing and the creation of start-up companies (Phan & Siegel, 2006; Powers & McDougall, 2005). In present, with the gradual change in the professional norms in academia and the diffusion of various support mechanisms inside universities, the role of technology transfer offices as "third party brokers" has increased considerably. Typically performing a mediating role and functioning as "boundary spanners", TTOs bridge cultural and value related barriers between "customers" (entrepreneurs/firms) and "suppliers" (scientists/universities) who operate in distinctly different environments (Siegel et al., 2003).

In particular, TTOs are instrumental in reducing the asymmetry of information between industry and science on the value of inventions as companies are not normally able to assess the quality of inventions ex-ante, and as inventors may have difficulty in assessing the business value of their inventions, particularly when they arise in new technology areas (Markman et al., 2005). Several recent studies have emphasized the role of the technology licensing office as both a locus for organizational learning about technology transfer (Feldman, Feller, Bercovitz, & Burton, 2002), and an important factor in licensing success (Siegel et al., 2003). It has also been argued that the technology transfer office plays a key role with respect to engendering academic entrepreneurship in relation to founding spin-offs (O'Shea, Allen, Chevalier, & Roche, 2005), by creating company formation expertise and synergy-generating networks between academics and venture capitalists, advisors and customers (Chugh, 2004; Munari & Toschi, 2011). Thus, as the prior research shows, it is expected that the presence of a technology transfer office will facilitate the academics' involvement in knowledge transfer through providing technical support, market expertise, and additional resources to patent and subsequently commercialize their patented inventions.

The evidence from previous exploratory research points to the possible positive effect the presence of a technology transfer office might have on women academics' involvement in knowledge transfer (Murray & Graham, 2007). As it is argued in a pair of companion papers (Ding et al. 2006), a lack of connections to members of the business community and industry players is likely to be a determining factor in female scientists' low rates of participation in various knowledge transfer activities. In particular, some studies, looking at the issue of academic engagement in commercial activities from a historical perspective, have suggested that women academics, being considered low-status members of the scientific community, were least committed to the ideals embodied in the "Mertonian norms" and most interested in different sorts of entrepreneurial activity, but nonetheless they encountered difficulties in engaging in such activities because of the lack of the necessary third-party support (Stuart & Ding, 2006).

The research by Murray and Graham (2007) shows that in the presence of a technology transfer office or other internal support structure women academics tend to use such formal institutional mechanisms to obtain resources and to learn about commercial science more often than their male peers. For men the TTO provides more of a "technical" value added in what regards the legal support, identification of lawyers and assistance in managing the licensing process. In exploratory studies, male interviewees viewed such a "third-party broker" as having little additional impact on their ability to establish connections to industry companies, while women academics described the "hand holding" provided by the TTO as "guiding them through an uncertain landscape" (Murray & Graham, 2007).

Coupled with the extensive evidence from previous studies on the lack of access to valuable industry connections and the high perceived time cost of looking for potential "buyers" of the invented technology for female academic scientists, we expect that the presence of a TTO at the respective university will increase the likelihood of female participation in patenting activities:

Hypothesis 2: The presence of a university's technology transfer office will increase the probability of observing a patent with at least one female academic inventor on the patent team.

3.3. The role of universities' IP regulations

Existing research on the role of internal support mechanisms has defined flexible and clear university policies related to technology transfer as one of the main organizational and managerial factors to consider in order to facilitate university-industry collaboration (Siegel, Waldman, Atwater, & Link, 2004). At the level of each university, patent policies are intended to rule the commercialization activities of academics and, as argued in the existing studies, have two main goals (Baldini et al., 2010). Firstly, they clearly define the rights of all parties involved in the transaction on both the academic and the industrial side, as well as their remunerations (if applicable). Specifically, the IP policy states to whom the invention must be disclosed and who is entitled to patent. Secondly, the internal IP policies, to the extent that they govern a university's involvement in and support for the technology-transfer activity, provide the basis for the legal, financial and marketing support for the individual academics involved in the process (Baldini et al., 2007).

To the extent that university regulations are destined to provide formalized and thus presumably clear information on the rules and procedures for technology transfer between academia and industry, as well as the support framework for patenting, we assume that for women academics, who have been evidenced to demonstrate generally more ambiguity and lack of information with regard to the patenting and subsequent commercialization process (Murray & Graham, 2007), the presence of such internal regulations may provide a considerable added value and will thus have a positive effect on increasing female participation in knowledge transfer activities.

In line with this reasoning, we put forward the following hypothesis:

Hypothesis 3: The presence of internal IP regulation will increase the probability of observing a patent with at least one female academic inventor on the patent team.

4. Methodology

4.1. Sample and data sources

Our data come from two main sources. The initial source was the APE-INV dataset which consists of patent applications filed the European Patent Office (EPO), with priority dates comprised between 1996 and 2007 and at least one inventor with an Italian address. The dataset is a result of a research project aimed at identifying university-owned and university-invented patents in Italy and other European countries. In this manner, it constitutes a perfect base to build reliable estimates of academic patenting in Italy throughout the 10-year period (see Lissoni et al., 2013 for a more detailed description of the dataset).

In order to obtain additional information needed for the present research (e.g. the names of the inventors on the patent team), we performed matching of the APE-INV dataset with the patent-level datathat were missing. These data were additionally retrieved from PATSTAT. Since the database does not provide the gender of the inventors, our next step was name disambiguation and assigning gender based on the inventor's first name. The dubious cases were double checked by searching the name of the inventor in question in the online directories, to obtain additional information from the references in the publications which could help establish whether the inventor is a male of a female.

For the university-level data, we used both secondary and primary sources. For the dates of introduction of IP regulations we turned to the study performed by Baldini, Grimaldi and Sobrero (2006) on Italian patenting where the authors provide the dates of IP policy adoption. For the missing cases, we contacted the technology transfer offices of the universities directly, by email. In the same manner we obtained the dates for the TTO creation for the universities from our sample.

After matching and cleaning the data, our sample includes information on 2538 Italian academic patents filed between1996 and 2007. For the purposes of the present research we adopt a definition of an "academic" patent utilized in the existing literature. Thus, we define "academic" a patent that was signed at least by one academic scientist, while working at his/her university, irrespective of whether the patent is owned by the university, a public research organization (PRO), the scientist, a business company or any other organization, either exclusively or jointly with other assignees (Dornbusch, Schmoch, Schulze, & Bethke, 2013; Lissoni, 2012; Lissoni et al., 2013). In terms of type of ownership, the sample contains 2034 university-invented academic patents, while 504 academic patents from the sample are university-owned (20% of the sample). In addition to that, 21% of the patents included in our sample have at least one female academic inventor. The main advantage of the sample we used is that it is geographically confined, which allows us to control for the differences that might arise from the contextual specificities (e.g. national policies and other specific public measures; socio-cultural and economic differences, etc.).

4.2.Variables

4.2.1. Dependent variable

In our regressions, we estimate the likelihood of having at least one female academic inventor among the inventors in the patent team. This measurement of female participation is common in the literature on gender gap in patenting activities (for instance, see Naldi et al. 2004; Mauleon & Bordons, 2009). We thus introduce a dummy variable equal “1” if at least one inventor on the patent team is a university-affiliated female, while it is equal “0” if otherwise.

4.2.2. Explanatory variables

The three main explanatory variables in our estimations are the ownership of the patent, the presence of a TTO, and the presence of an internal IP regulation at the priority date.

Concerning patent ownership, we construct a dummy variable (UNI_OWN) which is equal “1” if the patent is either owned or co-owned by the university (that is, there is at least one university listed as applicant of the patent); “0” if otherwise.

The presence of a TTO is measured by a dummy variable equal “1” if a TTO existed at the priority date of the patent[3]; “0” if otherwise. In a similar way, the presence of an internal IP regulation at the university is measured by a dummy variable equal “1” if an IP regulation existed at the priority date of the patent[4]; “0” if otherwise Since we take the inventor’s university of affiliation as the reference university for the construction of these two variables, in cases of inventors affiliated with different universities at the time of patenting, we acknowledge the presence of a TTO/IP regulation if at least one of these universities had a TTO/IP regulation in place at the priority date.

[3]If there are inventors from more than one university, we take the university with the oldest date of the TTO creation.
[4]If there are inventors from more than one university, we take the university with the oldest date of the IP regulation.

4.2.3. *Control variables*

We included a series of control variables in our estimations, in order to reduce unobserved heterogeneity that might affect the probability to obtain the expected result.

In particular, at the patent level, we control for the number of inventors on the patent team (NUM_TEAM); as mentioned before, women scientists have been found to engage in larger patent teams as compared to men (Mauleon & Bordons, 2009), which may indicate their higher propensity to collaborate, so we would expect a higher probability of female participation in patents with larger patent teams.

The variable that accounts for the academic position, i.e. seniority, of the inventors on the patent team controls for the fact that there might exist an overt discrimination and bias among the older academic peers with regard to their female colleagues, so that they will tend to avoid having women inventors in their teams. We expect that, ceteris paribus, there will a higher share of female participation among the patents with less senior patent team members (AVERAGE AGE). To control for the effect of seniority, we also introduce a dummy variable FULL equal "1" if there is at least one full professor on the patent team, and "0" if otherwise.

Lastly, we control for such university-level variables as the size and region of the university of inventor's affiliation to proxy for the quality of the university of affiliation of the inventor. As argued in the literature, more prominent universities tend to be more active in patenting due to larger R&D and patenting budgets, and they are more likely to employ "star" scientists who are more productive and better connected with the external environment (Rasmussen, Moen, & Gulbrandsen, 2006). As for the geographic influence, in Italy the northern regions have been traditionally more endowed with resources as compared to the central and southern regions, so we might expect that universities situated in the north of the country will be better placed to engage more extensively in patenting and commercialization activities. For the university's size, we adopt the following classification of the Italian universities based on the number of students (as of year 2009): Large - over 20.000 students; Medium - 10.000-20.000 students; Small - less than 10.000 students. For the patents where inventors come from several universities of different size, we choose the size of the university from which come the majority of inventors on the patent team. The dummy variables which control for the university's region (NORTH, CENTER, SOUTH) were constructed based on the accepted classification[5]. CENTER dummy variable is the baseline case. For the patents with the inventors coming from the universities from various regions, we take the university's region from which most inventors on the patent team come from.

5. Results

5.1. Descriptive statistics

In the results section, we first provide descriptive statistics to account for the temporal trends in the evolution of Italian academic patenting by type of ownership, as well as with regard to the female participation in such academic patents (Table 2 presents the descriptive statistics on the variables included in our sample, whereas Table 3 presents the correlation matrix).

Insert Table A2 about here

Insert Table A3 about here

Figure 1 provides the patent distribution by type of ownership:

Insert Figure A1 about here

[5] North of Italy includes the following regions: Lombardia, Piemonte, Valle d'Aosta, Trentino Alto Adige, Friuli Venezia Giulia, Liguria, Veneto. Center comprises of: Emilia Romagna, Lazio, Tuscany, Marche, Abruzzo, Sardinia. The South includes: Molise, Basilicata, Sicily, Puglia, Campania.

As it can be seen from the figure above, university-invented patents considerably prevail over the university-owned, even though there has been a marked increasing trend in Italian university ownership over the years. This is consistent with the existing evidence on a growing control exerted by universities on IP over their scientists' inventions, as a result of their increased autonomy starting in the second half of the 1990s (e.g. Lissoni et al., 2013). In particular, with the advent of autonomy, several Italian universities introduced explicit IP regulations starting from 1995, and by 2008 over 70% of Italian universities had adopted one (Baldini et al., 2010; Lissoni et al., 2013). This evolution is vividly depicted in the Figure 1. However, in spite of the important changes in the autonomy and IP regulation at university level, the share of academic patents with university ownership still remains significantly lower as compared to the share of university-invented academic patents (see Figure A2).

Insert Figure A2 about here

For the purposes of our research, we then specifically look at the distribution of academic patents with female participation. Since not all women on the patent team may be from academia (i.e. they were not university-affiliated at the time of the patent (priority year)), we control for this by distinguishing between the patents with at least one university-affiliated (academic)[6]female inventor, and investigate whether the share of such academic patents tends to grow over the years.

We further explore whether there are any differences in terms of the effect of the type of ownership, in line with one of our hypotheses regarding the effect of institutional ownership on the share of female participation. As it can be seen in the figure below, the distribution by year of academic patents including at least one female academic inventor reveals the higher participation of female academics in university-invented patents, as compared to the university-owned ones. This could be

[6]We use the term “university-affiliated” and “academic” interchangeably to say that an inventor comes from academia.

explained by the higher share of university-invented vs. university-owned patents in the general structure of academic patenting, as depicted in Figure 2. However, after 2003 the growing trend of the university-owned patents with female participation has become much more pronounced, exceeding the share of university-invented patents in 2007 and reaching almost 20% in that same year (see Figure A3).

Insert Figure A3 about here

The growth in the share of university-owned academic patents with at least one university-affiliated female has been uneven, demonstrating a drastic decline in the year 1999, resuming the growth in the years 2000 and 2001. However, after the year 2001 the share of university-owned patents with female participation decreased again, while the percentage of university-invented patentscontinued to grow. This could be explained by the fact that the introduction of a "professor's privilege" in Italy in 2001 (the Law 383/2001) may have had temporary adverse effect on the general amount of the academic university-owned patents due to a drastic shift from the institutional ownership and the adjustment of the whole system. The previous figures (e.g. Figure 1 for academic patents) do not, however, exhibit such a vivid decline in the year 2002 for university-owned patents in general. The share of university-invented patents with the female academic participation demonstrated, on the contrary, the growing trend which culminated in 2003. This situation may point to a higher propensity of female academic inventors to assign the IP rights on the patented inventions to the industry in the period right after the introduction of the "professor's privilege" in Italy, or collaborating more with the inventors from industry when the IP rights for the joint research results would go to the industry. As the graph further shows, the share of university-owned patents with female participation started to grow again after the year 2004 when the new IP law (approved 23rd December 2004) reversed Law 383 for inventions, made by public employees, arising from research financed at least partially by the private sector, or stemming from specific research projects funded by public organizations other than the inventors' organization(s), by granting IPRs on such inventions to the public employers rather than the employees (Baldini et al., 2006).

In general, as the descriptive statistics show, there has been a growing trend in the participation by Italian female academic inventors in patenting. The results also demonstrate that the number of university-owned patents with female participation has been steadily increasing over the years, exceeding the share of patents with non-institutional ownership in the last year of our observation.

5.2. Regression results

Table A4 (see the APPENDIX A) displays the marginal effects for the set of probit estimations where the dependent variable is the probability of having at least one female academic inventor on the patent team. The first specification includes only control variables, while the second specification includes the type of ownership dummy. In the specifications three and four the variables for the presence of a TTO and IP regulation are introduced respectively, while the last, fifth, specification provides a full model with the whole set of variables. According to the hypothesis put forward in one of the previous sections, the university ownership will tend to increase the likelihood of having a female academic inventor as compared to other types of ownership (e.g. by a company or an individual). Moreover, we have hypothesized that the presence of university-level mechanisms in support of patenting and technology transfer – such as the technology transfer office and the internal IP regulation – will as well increase the probability of patents with at least one female academic in the inventors' team. As the results demonstrate, these hypotheses, related to the role of university-level support mechanisms, are supported in our estimates.

Insert Table A4 about here

The results of the respective regressions show that university-owned patents demonstrate a higher probability to have at least one female academic inventor in the patent team, as compared to university-invented patents. Indeed, the coefficient of the dummy variable University-owned is positive and statistically significant (at the 1% level) in both Model 2 and in Model 5. Besides that, also our second hypothesis is confirmed, given that the presence of a TTO has a positive and statistically significant (at the 1% level both in Model 3 and in Model 5) effect on the probability of having female academic presence in the patent team. For what concerns our third hypothesis, it is confirmed in Model 4, when we separately include the dummy IP regulation in the Model (the coefficient of the variable is positive and statistically significant at the 1% level in this model), and in the full model, at 10% significance level. The results of our analysis point to the instrumental role of the university in general, as well as its specific IP policies and the TTO as the support structure which may add enhanced value for female researchers through acting as a broker between the individual inventor and the internal and external stakeholders.

The effect of some of the control variables is significant as well. Thus, in line with the existing studies mentioned above (Mauleon & Bordons, 2009; Naldi et al., 2004), women academic inventors are more likely to be found in the patent teams with a larger number of inventors. The probability of female participation also increases when there is at least one full professor in the team. This may suggest that tenure facilitates the involvement of academic female inventors in the patenting arena, as it allows to circumvent some of the gaps previously described. With that, the variable controlling for the average age of the patent team members affects negatively on the likelihood of female participation. In addition to that, the dummy variable South is negative and statistically significant in our models. This suggests that, when the majority of co-inventors come from the less economically developed regions of Southern Italy, the likelihood of an active participation of women academics in patenting activity decreases. There are therefore important contextual influences which affect this kind of behaviour. We do not find, on the other hand, any statistically significant effect related to the size of the university to which the inventors are affiliated.

5.3.Robustness checks

We performed a series of robustness checks in order to validate our results. Specifically, we ran the same set of regressions excluding the control variable team size due to its potential endogeneity; however, our check has not revealed any alteration to the previous results.

Besides, in alternative to the dependent variable we used in our analysis, i.e. a dummy variable indicating whether there is at least one university-affiliated female inventor on the patent team, we construct and introduce to the model alternative variables measuring female participation. Thus, we run additional regressions with the dummy variables indicating whether the share of female academic inventors on the patent team was equal 10%, 20% and 30% respectively[7]. The results remain invariant[8].

6. Discussion and conclusions

In this paper we have addressed the role of university IP polices and structures on the likelihood to involve women academic researchers in patenting activity. We explored the role of university IPR ownership (comparing university-owned and university-invented patents), the presence of a technology transfer office and the introduction of an IP regulation in the university. We tested a set of hypotheses on such issues on a sample of academic patents from Italy. The descriptive part of our study vividly depicts that there has been a growing trend in participation in patenting activity by Italian female academic scientists over the 10-year period of the study. An important finding of the present research is that there has been considerable growth in the share of university-owned patents with at least one female academic inventor on the patent team, which in 2007 outpaced the share of patents with other types of ownership (e.g. by a firm or an individual). This points to the increasing

[7] These are the shares of female participation, which are most represented in our sample.
[8] The results of the regressions with alternative dependent variables are available from the authors upon request.

positive impact of the institutional ownership on female participation in patenting and in other stages of an innovation process within academia.

With our study, we tried to further explore this observation by testing the hypotheses on the university internal policies and mechanisms that might play an instrumental role in fostering broader participation of female inventors. The results of our econometric analysis confirm that the university ownership and the presence of a dedicated unit in support of commercialization have a significant positive role in increasing the female participation in patenting activities. Our findings are in line with the results of the qualitative research previously conducted in another national setting, the United States (Murray & Graham, 2007), and which evidenced that women academics happen to be more responsive to the presence of such internal support structures as a technology transfer office, as they tend to perceive them as "a hand holding" when engaging in patenting or other knowledge transfer activities. Apparently, as supported by the results of our empirical analysis, the presence of a university's TTO increases the share of female participation in patenting. The positive effect may take place due to the increased value added for women scientists of the TTO's services and assistance in accessing the resources critical for defining potential venues for commercial exploitation of the research, as well as providing links to the external stakeholders (e.g. industry, venture capitalists) and "brokering" for the successful commercialization, which is an important prerequisite for patenting. In comparison to men, female academic inventors have been found to be in a much more disadvantaged position (Rosser, 2009, Rosa & Dawson, 2006), and therefore, as the results of our study demonstrate, the effect of the TTO will be positively correlated with this group of academic scientists.

However, further research is needed to analyze in more detail the specific mechanisms by which a university's technology transfer office may enhance the participation of women academic scientists in patenting. Besides that, an important issue that should be addressed by future research is the involvement of women academic scientists in the actual commercialization of patented inventions, for instance through licensing or spin-off formation. Country-specific studies will also be needed to explore the role of university and its internal support mechanisms in other national contexts which are characterized by different socio-cultural and policy environments. Future research could also be extended to include the investigation of the effect of other policy measures at the university level as, for instance, paternity leave policy or a set of explicit gender policies addressing the valorisation of gender diversity at the workplace.

In terms of the contribution, a particular feature of the present research is that, being placed in a national context, it creates an added value at two levels: organizational (university) and country level, in the form of policy implications for both universities and national governments in the field of gender equality in science and academia respectively. This happens to be of particular relevance in the situation of an ever increasing awareness and sharp concern about the underlying factors behind the gender gap in scientific and, more recently, commercial involvement of academic scientists (Frietsch et al., 2009; Technopolis, 2008). As in many countries the focus for scientific research has been shifting from basic to applied research and innovation, for which one of the primary indicators is patents granted (Rosser, 2009), failure to introduce effective and relevant measures and mechanisms aimed at addressing the gender gap in patenting will lead to reduced competitiveness and innovative growth in the long run. At the organizational level, since patents have recently become a marker of success and peer recognition in some industries, women's low percentages in patenting may significantly reduce their engagement with the industry and will, thus, inhibit considerably their professional advancement (Rosser, 2009). The results of our research highlight the role of a university in addressing this gender gap and in promoting higher participation of women scientists in knowledge transfer through various institution-level mechanisms and instruments. In this manner, with the present study we provide an empirical basis for country- and organization-level policies advancing state-of-the-art understanding of the institutional mechanisms which may reduce the gender gap in productivity and in commercial engagement within academia resulting an important measure of effective utilization of qualified human resources necessary for sustainable growth and development.

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APPENDIX A

Figure A1 - Number of academic patents by type of ownership for the period 1996-2007:

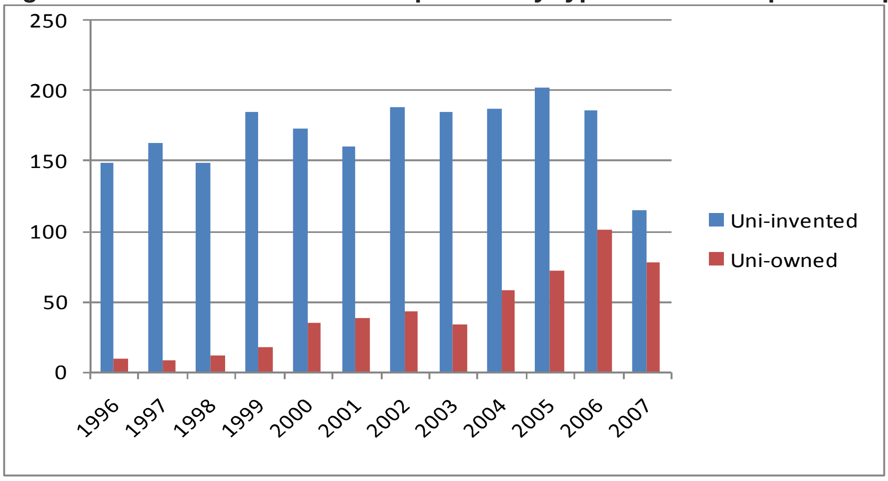

Figure A2 -% of academic patents by type of ownership for the period 1996-2007:

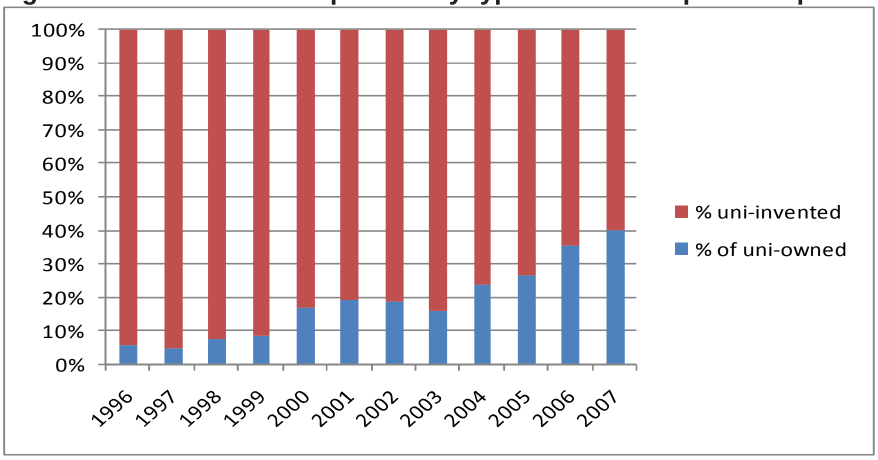

Figure A3- % of patents with at least one *academic* female, by year and type of ownership

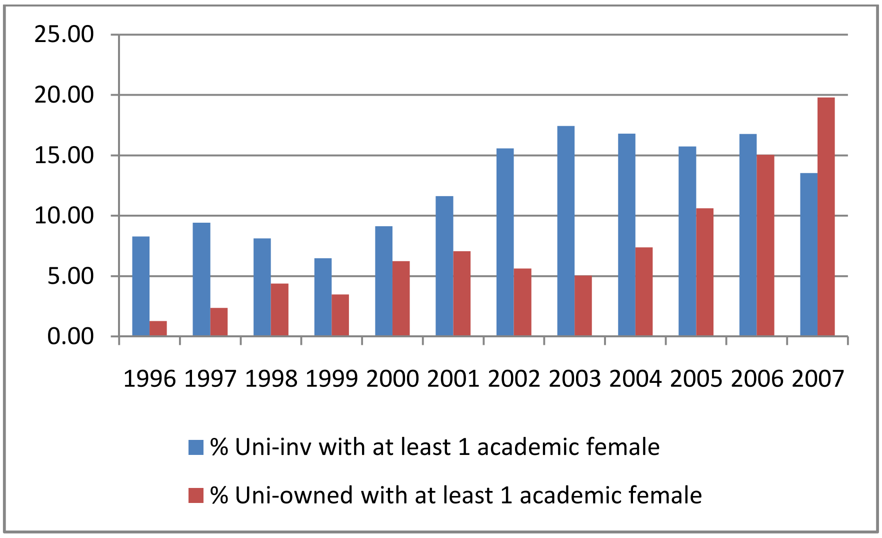

Table A1. Definition and measures of the variables

Variable name	Variable description
Dependent variable:	
FEMALE_UNI	Dummy variable equal "1" if at least one inventor on the patent team is university-affiliated female; "0" if otherwise
Explanatory variables:	
UNI_OWN	Dummy variable equal "1" if the patent is owned/co-owned by university; "0" if otherwise
TTO	Dummy variable equal "1" if a TTO existed at the priority date of the patent[9]; "0" if otherwise
IP	Dummy variable equal "1" if there was an IP regulation in place at the priority date of the patent[10]; "0" if otherwise
Control variables:	
TEAM SIZE	Continuous variable measuring number of inventors on the team
AVERAGE AGE	Average age of the inventors on the patent team
FULL	Dummy variable equal "1" if there is at least one full professor on the patent team; "0" if otherwise
SIZE	LARGE - the majority of inventors on the patent team come from large universities[11]; "0" if otherwise
	MEDIUM - the majority of the inventors on the patent team come from the medium-size universities; "0" if otherwise
	SMALL - the majority of the inventors on the patent team come from the small universities; "0" if otherwise (baseline)
NORTH	Dummy variable equal "1" if the majority of the inventors on the patent team come from the

[9] If there are inventors from more than one university, we take the university with the oldest date of the TTO creation.
[10] If there are inventors from more than one university, we take the university with the oldest date of IP policy introduction.
[11] We adopt the following classification of the Italian universities based on the number of students (as of year 2009): Large - over 20.000 students; Medium - 10.000-20.000 students; Small -less than 10.000 students.

	universities from North of Italy[12]; "0" if otherwise
CENTER	Dummy variable equal "1" if the majority of the inventors on the patent team come from Center of Italy; "0" if otherwise (baseline)
SOUTH	Dummy variable equal "1" if the majority of the inventors on the patent team come from South of Italy; "0" if otherwise[13]

Table A2.Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
FEMALE_UNI	2538	.208	.406	0	1
UNI_OWN	2538	.199	.399	0	1
TTO	2538	.465	.499	0	1
IP	2538	.686	.464	0	1
SIZE TEAM	2538	3.428	1.875	1	14
AVERAGE AGE	2538	49.931	9.261	27	75
SOUTH	2538	.150	.358	0	1
NORTH	2538	.441	.496	0	1
CENTER	2538	.407	.491	0	1
LARGE	2538	.803	.397	0	1
MEDIUM	2538	.168	.374	0	1
SMALL	2538	.027	.163	0	1
FULL	2538	.620	.486	0	1

[12] North: Lombardia, Piemonte, Valle d'Aosta, Trentino Alto Adige, Friuli Venezia Giulia, Liguria, Veneto ; Center: Emilia Romagna, Lazio, Tuscany, Marche, Abruzzo, Sardinia; South: Molise, Basilicata, Sicily, Puglia, Campania

[13] In the cases when there is even number of the inventors coming from the universities from various regions, we take the region of the largest university.

Table A3. Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.Female_uni	1.00												
2.Uni_own	0.23*	1.00											
3.TTO	0.16*	0.21*	1.00										
4.IP	0.13*	0.16*	0.47*	1.00									
5.Team size	0.23*	0.02*	0.15*	0.12*	1.00								
6.Average age	-0.16*	-0.12*	-0.06*	-0.02*	-0.09*	1.00							
7.South	-0.05*	-0.06*	-0.01	-0.04*	0.02*	-0.04*	1.00						
8.North	0.04*	0.04*	0.15*	0.09*	-0.06*	-0.12*	-0.38*	1.00					
9.Center	-0.00	0.00	-0.14*	-0.07*	0.05*	0.15*	-0.35*	-0.74*	1.00				
10.Large	0.03*	-0.013	0.06*	0.23*	0.01	0.09*	0.00	0.09*	-0.09*	1.00			
11.Medium	-0.03*	0.03*	-0.10*	-0.18*	0.00	-0.09*	-0.01	-0.14*	0.14*	-0.91*	1.00		
12.Small	-0.01	-0.03*	0.09*	-0.15*	-0.03*	-0.01	0.00	0.08*	-0.09*	-0.34*	-0.08*	1.00	
13.Full	0.04*	0.08*	-0.05*	-0.02*	0.18*	0.33*	0.02*	-0.09*	0.08*	0.02*	-0.03*	0.01	1.00

Table A4. Marginal effects, probit estimations of likelihood of having at least one female academic inventor on the patent team

Variable	(1) Controls only	(2)Uni_own	(3)TTO	(4)IP	(5)Full Model
Team size	0.042***	0.043***	0.037***	0.039***	0.039***
	(0.004)	(0.004)	(0.004	(0.004)	(0.004)
Average age	-0.008***	-0.007***	-0.008***	-0.008***	-0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
South	-0.062***	-0.052**	-0.068***	-0.061***	-0.057***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
North	0.017	0.017	0.001	0.009	0.004
	(0.017)	(0.017)	(0.018)	(0.017)	(0.018)
Medium	-0.024	-0.038	0.01	-0.047	-0.029
	(0.052)	(0.049)	(0.055)	(0.049)	(0.05)
Large	0.01	0	0.032	-0.036	-0.006
	(0.05)	(0.05)	(0.047)	(0.056)	(0.051)
Full	0.059***	0.036**	0.065***	0.060***	0.043**
	(0.017)	(0.018)	(0.017)	(0.017)	(0.018)
Uni_own		0.206***			0.178***
		(0.023)			(0.024)
TTO			0.106***		0.059***
			(0.016)		(0.019)
IP				0.088***	0.038*
				(0.016)	(0.02)
Observations	2,538	2,538	2,538	2,538	2,538

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1