ECONSTOR
Make Your Publications Visible.

A Service of
ZBW
Leibniz-Informationszentrum Wirtschaft
Leibniz Information Centre for Economics

Bellucci, Andrea; Pennacchio, Luca

Working Paper

University knowledge and firm innovation: Evidence from European countries

IAW Diskussionspapiere, No. 113

Provided in Cooperation with:
Institute for Applied Economic Research (IAW)

Suggested Citation: Bellucci, Andrea; Pennacchio, Luca (2014) : University knowledge and firm innovation: Evidence from European countries, IAW Diskussionspapiere, No. 113, Institut für Angewandte Wirtschaftsforschung (IAW), Tübingen

This Version is available at:
https://hdl.handle.net/10419/118600

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

WWW.ECONSTOR.EU

Mitglied der Leibniz-Gemeinschaft

IAW DISCUSSION PAPERS

iaw@iaw.edu | www.iaw.edu

IAW Diskussionspapiere Nr. 113 November 2014 | No. 113 November 2014

University Knowledge and Firm Innovation – Evidence from European Countries

Andrea Bellucci
Luca Pennacchio

Institut für Angewandte Wirtschaftsforschung e.V.
Ob dem Himmelreich 1 | 72074 Tübingen | Germany
Tel.: +49 7071 98960 | Fax: +49 7071 989699

ISSN: 1617-5654

IAW-Diskussionspapiere

Das Institut für Angewandte Wirtschaftsforschung (IAW) an der Universität Tübingen ist ein unabhängiges Forschungsinstitut, das am 17. Juli 1957 auf Initiative von Professor Dr. Hans Peter gegründet wurde. Es hat die Aufgabe, Forschungsergebnisse aus dem Gebiet der Wirtschafts- und Sozialwissenschaften auf Fragen der Wirtschaft anzuwenden. Die Tätigkeit des Instituts konzentriert sich auf empirische Wirtschaftsforschung und Politikberatung.

Dieses IAW-Diskussionspapier können Sie auch von der IAW-Website als pdf-Datei herunterladen:

http://www.iaw.edu/index.php/IAW-Diskussionspapiere

ISSN 1617-5654

Weitere Publikationen des IAW:

- IAW News (erscheinen 4x jährlich)
- IAW Impulse
- IAW Forschungsberichte

Möchten Sie regelmäßig eine unserer Publikationen erhalten? Dann wenden Sie sich bitte an uns:

IAW e.V. Tübingen, Ob dem Himmelreich 1, 72074 Tübingen,
Telefon +49 7071 98 96-0
Fax +49 7071 98 96-99
E-Mail: iaw@iaw.edu

Aktuelle Informationen finden Sie auch im Internet unter:

http://www.iaw.edu

Für den Inhalt der Beiträge in den IAW-Diskussionspapieren sind allein die Autorinnen und Autoren verantwortlich. Die Beiträge stellen nicht notwendigerweise die Meinung des IAW dar.

University knowledge and firm innovation. Evidence from European countries*

Andrea Bellucci
(*IAW – Institute for Applied Economic Research at the University of Tübingen*)

and

Luca Pennacchio**
(*Department of Economics and Statistics, University of Naples Federico II*)

Abstract

In recent decades firms have intensified the exploration of external sources of knowledge to enhance their innovation capabilities. This paper presents an empirical analysis of the factors that affect the importance of academic knowledge for firms' innovative activities. An integrated approach that simultaneously considers country-level and firm-level factors is adopted. Regarding the former factors, the analysis shows that the entrepreneurial orientation of university and the quality of academic research increase the importance of knowledge transfers from universities to firms. This suggests that the environmental and institutional context contribute to explain cross-national disparities in university-industry interactions and in the effectiveness of knowledge transfer. In regard to the latter factors, the results indicate that firms oriented toward open search strategies and radical innovations are more likely to draw knowledge from universities. Furthermore, firms belonging to high technology sectors and firms with high absorptive capacity place greater value on the various links with universities. With respect to firm size the estimates show an inverted U-shaped relation with the importance of universities as a source of knowledge. However, the greatest benefits from interacting with universities are achieved by small and young research-active firms.

Keywords: Innovation; industry-university links; knowledge transfer; university entrepreneurial orientation

JEL classification: O32; O33; L20

---

* This paper has been presented at the International Conference on Technology Transfer held in Urbino (Italy) on October 30-31, 2014.We are grateful for comments and suggestions from Francesco Venturini (discussant) and participants at this conference. We thank Lisa Tarzia for the revision of the paper. Andrea Bellucci (andrea.bellucci@iaw.edu) acknowledges the support from the FP7 Marie Curie Actions of the European Commission, via the Intra European Fellowship (Grant Agreement Number PIEF-GA-2012-331728). Luca Pennacchio (l.pennacchio@unina.it) acknowledges the support of REPOS project. All remaining errors are our own.

** *Corresponding author*: Department of Economics and Statistics, University of Naples Federico II, Via Cintia, 45 - Monte S. Angelo, 80126 Napoli, Italy. Phone: (+39) 081 675013, Fax: (+39) 081-675014.

1. Introduction

Recently in modern knowledge-based economies, a considerable amount of interest has been placed on the interaction between university and industry. This focus is due to the fundamental role of scientific knowledge in spurring firms' innovation, especially in science- and technology-based sectors (Klevorich, 1995; Shan et al., 1994; Meyer-Krahmer and Schmoch, 1998; Stuart et al., 2007) and in turn, in fostering economic development and competitiveness (Jaffe, 1989; Griliches, 1998; Cohen et al., 2002). Scholars have developed the concept of the 'innovation system' to highlight that the interactions among a variety of factors are the driving force of innovation. In some of these models, as for example in the triple helix model of academic-industry-government relations (Etzkowitz, 1983), universities assume a leading role in the creation of technological innovation and are seen as engines of growth (Feller, 1990; Etzkowitz et al., 2000; Etzkowitz and Leydesdorff, 2000; Audretsch et al., 2013).

In line with the growth of a global knowledge economy, many European countries have implemented reforms of national research systems, aiming to increase the commercialization of research and the transfer of knowledge from university to industry. The focus of policy makers has shifted towards the so-called 'third mission of universities': in addition to the basic functions of teaching and research, universities are required to contribute to society through knowledge and technology creation, transfer and exchange. As a consequence, many universities have evolved from a traditional institution characterized as an 'ivory tower' to an 'entrepreneurial university' with strong ties with industry and a more active role in promoting the transfer of knowledge to industry (Clark, 1998; Etzkowitz, 1983; Bercovitz and Feldmann, 2006; Rothaermel et al., 2007).

However, despite growing linkages, European firms still exhibit a rather limited ability to commercialize new scientific knowledge, in comparison to their US or Japanese counterparts (Bergman, 2010; Lehrer et al., 2009; Owen-Smith et al., 2002; Mueller, 2006). To this point, the European Commission Directorate-General for Economic and Financial Affairs (ECFIN) has coined the term 'The European Paradox' to indicate that although European universities and research institutes generate a great amount of knowledge, such scientific knowledge is not often exploited for social and economic needs. Veugelers and Del Rey

(2014) argue that the low level of industry-science linkages can be attributed to a lack in demand on the firm side and/or a lack of appropriate incentive structures and supportive institutional factors on the science side.

A growing literature tried to empirically test the relationship between university and industry, investigating factors that explain why firms draw from universities for their innovative activities. In particular, Laursen and Salter (2004) use a sample of 2,655 manufacturing firms from the UK Innovation Survey to analyze the determinants of a firm's propensity to use university research in their activities. The authors suggest that firm structural factors such as size and age, as well as an open approach towards external sources of knowledge play a crucial role in shaping the use of university knowledge.

Expanding on these findings, the present paper seeks to gain a better understanding of the factors that make universities important sources of knowledge for innovative activities from the firm perspective. In addition to firm-specific variables, the analysis examines cross-national differences in the characteristics of national innovation systems and the role of universities within them.

The paper differentiates and contributes to the extant literature on industry-science links in several ways. Firstly, the analysis is directly focused on an evaluation by firms of knowledge flows generated in the university-industry interaction rather than on the actual determinants of this relationship. In contrast with previous studies that concentrated primarily on the factors that influence the probability of linkages between firms and universities, a different approach is adopted which looks beyond whether cooperation occurred or not, towards assessing the efficiency of such an interaction.

Secondly, while most existing studies have analyzed the micro-factors that influence the transfer of knowledge, very little research has concerned the importance of the environmental or institutional context. On this point, existing studies like Laursen and Salter (2004) are distinctive due to their explicit consideration of the impact of macro-factors on the transfer of knowledge from university to industry. While there exists theoretical papers which have highlighted the influence of legal, economic and policy environments on the rate of technological change (Bercovitz and Fieldmann, 2006; Lehrer et al., 2009;

Tijssen; 2006), far too little attention has been paid to the empirical analysis of such macro-factors. Therefore, the intention of the present study is to fill this gap by providing some empirical evidence on the macro-factors that determine deep variations across countries in the importance of university knowledge for firms' innovation. An integrated empirical approach that simultaneously considers demand-side factors, captured through firm-specific variables, and supply-side factors and environmental characteristics, captured with variables related to national university systems is adopted. In doing so, the analysis departs from the usual focus on individual universities and adopts a national perspective on the entrepreneurial role that universities play in the process of knowledge transfer.

Thirdly, in addition to confirming and expanding on findings from previous studies, the econometric model used allows for an in-depth analysis on how firm-specific characteristics explain the use of universities as a source of external knowledge.

Lastly, the paper presents a large scale cross-country and cross-industry empirical analysis, whereas most of previous research is hindered by a focus on a limited number of technological sectors, such as biotechnology or ICT, and relied on small samples or case studies.

The econometric analysis is based on a sample of innovative firms from 14 European countries belonging to manufacturing and services sectors, drawn from the Community Innovation Survey (CIS) 2008. The dependent variable measures the degree of importance of universities as a source of knowledge for the innovative activities of firms, ranging from zero for firms not using universities at all, and three, for firms that attribute high value to knowledge generated at universities. Given the qualitative nature of the variable, an ordered regression model is estimated.

The most interesting results concern the role of the research system in determining the value of scientific knowledge for industry and in explaining cross-national disparities. The estimates show that universities are considered more important sources of knowledge in countries with a higher entrepreneurial orientation of their universities and higher quality of academic research. The paper then provides empirical support to

theoretical frameworks that emphasize the relevance of environmental and institutional conditions in fostering university-industry linkages.

Furthermore, in regard to firm-related factors, the analysis indicates that the extent to which firms benefit from university knowledge is also shaped by their internal strategies for knowledge exploration and exploitation, as well as their structural characteristics. Firms that rely broadly on external sources of information, on innovation cooperation and are more inclined toward more radical product/process innovations place higher value on academic knowledge. In addition, firms belonging to technology or knowledge intensive sectors and firms with high absorptive capacity (captured by the intensity of in-house R&D expenditures) draw more from universities in their innovative activities. With respect to firm size, the evidence is mixed: an increase in size increases the value attributed to academic knowledge but at a decreasing marginal rate. This may conciliate the opposing results of previous studies. Finally, the greatest value is perceived by small and young firms that perform in-house R&D.

The remainder of the paper is organized as follows. Starting with the theoretical and empirical background about industry-university linkages, Section 2 then develops the research hypotheses. Section 3 describes the data and the econometric model used to test the hypotheses. Section 4 discusses the results and Section 5 concludes.

2. Theoretical framework and hypotheses development

The increasing importance of knowledge in modern regional and national innovation systems implies a larger role of knowledge producing and disseminating institutions like universities in industrial innovation. The literature on university-industry linkages has considerably increased in recent decades, recognizing universities and other research institutions as key actors for economic growth and international competitiveness. Researchers have analyzed the transfer of knowledge generated in such relationships, centering their attention on the variety of knowledge transfer mechanisms (Bekkers and Bodas Freitas, 2008; D'Este and Patel, 2007; Geuna and Muscio, 2009; Landry et al., 2010) and on the characteristics of involved actors.

In general, factors affecting the process of knowledge and technology transfer can be divided into two broad categories: one concerning demand-side factors, i.e. factors related to individual firms (Laursen and Salter, 2004; Santoro and Bierly, 2006; Fontana et al., 2006, Yli et al., 2001; Mowery et al., 1996; Van Wijk et al., 2008), and another concerning supply-side factors, i.e. factors related to individual universities (Siegel et al., 2003; Azagra-Caro, 2007; Schartinger et al., 2001; Link et al., 2007; Friedman and Silberman, 2003; Caldera and Debande, 2010; D'Este and Perkmann, 2011). The present paper extends this literature investigating the impact of the environment and institutional context, with a particular focus on the role of national university systems.

Some theoretical models and conceptual frameworks developed to understand university-industry relationships and their role in knowledge-based innovation systems have highlighted the importance of environmental factors. In describing his "*Contingent Effectiveness Model of Technology Transfer*", Bozeman (2000) recognizes the active role of governments and universities in technology development and transfer. Governments can operate as producers of research, supplying applied research and technology to industry, or as brokers, developing policies for industrial technology development and innovation. From this point of view, legislative initiatives are crucial to fostering R&D cooperation among actors, in particular, in creating a favorable environment for university-industry interaction.

Bercovitz and Feldmann (2006) propose an evolutionary scheme where such relationships are formed through a series of formal and informal channels and are influenced not only by firm and university characteristics and strategies but also by the policy context for innovation. In such a framework, the legal, economic and institutional environments determine the role and the type of university knowledge production and the entrepreneurial orientation of university and research systems.

From the variety of environmental factors that can affect university-industry relationships, Lehrer et al. (2009) focus on university entrepreneurship. The authors show that variations in country-level university entrepreneurialism explain differences in firms' innovation output (measured in terms of patents filed to the EPO). Tijssen (2006) develops a theory and a measurement model for identifying a university's entrepreneurial orientation. The author defines entrepreneurial universities as those with "*latent or emerging capabilities to create new resources and/or to utilize existing resources and facilities in such a way that results of intra-mural research and development activities are exploited and commercialized as assets (services, products, or related processes) that can be traded on the open market within a competitive business setting through a new or existing enterprise*". He proves that the entrepreneurial orientation of a university, alongside many other country-level and institutional factors, is of significant relevance for investigating university-industry interactions at macro-level.

The literature proposes several definitions of an entrepreneurial university. However, in the various definitions 'entrepreneurial' is largely synonymous with 'commercial': entrepreneurial universities shift their knowledge production bases towards problem-oriented research and the commercialization of results, playing an important role in realizing economic innovations. As such, universities that embrace their role within the triple helix model of the university-industry-government relationship and that adopt a mission of contributing to industrial innovation and, in turn, to regional/national development, can be considered as entrepreneurial universities (Mavi, 2014).

Several further supply-side factors have been identified in the literature as determinants of knowledge transfer process to industry: the quality of academic knowledge; the size of universities; the diversification of

faculties and disciplines; and the seniority and the gender of researchers (Link et al., 2007; Martinelli et al., 2008; Mathieu, 2011). Among these factors, academic quality is certainly the key driver of university-industry interaction. The quality of research produced by university influences industrial innovation by opening up new opportunities for product/process innovations. As noted by various authors, innovative firms make extensive use of research performed in high quality research universities, published in quality academic journals and cited frequently by academics themselves (Mansfield, 1991; Mansfield and Lee, 1996; Narin et al. 1997). There is also empirical evidence that suggests a preference of firms for high quality research universities. Mansfield (1995), for example, using data from 66 manufacturing firms and 200 academic researchers, demonstrates that high quality research universities provide a greater contribution to firm innovation. Furthermore, Petruzzelli (2011) shows that the value of innovation jointly performed by firms and universities, measured by the number of citations to joint patents, is positively affected by the university's reputation for research excellence.

This set of arguments leads to the formulation of the main hypotheses of the paper.

H1a. The characteristics of innovation and R&D systems determine the importance of academic knowledge for industry innovation. By having research activities in the industry relevant field of science and an active role in knowledge transfer processes, university systems with entrepreneurial orientation should enhance the importance of knowledge transfer to industry.

H1b. University system characterized by high quality research provide a greater contribution to industrial innovation, generating and transferring highly valued knowledge for firms' innovative activities.

The remaining hypotheses refer to the demand for university knowledge, in accordance to previous research on the topic. This strand of literature indicates that universities are part of the firm's overall strategy for searching and exploring new knowledge. The search strategy research program highlights that private organizations have reorganized, outsourced and shifted their knowledge creation activities, including R&D, by means of cooperation with a wide range of different organizations. The basis for this process is the recognition that a firm's innovation capacity depends not only on internal R&D activities, but also on

external ideas and resources. In line with the *open innovation* paradigm (Chesborough, 2003), a firm's ability to make use of external sources of knowledge is of strategic importance for innovation, especially in a social and economic environment requiring the continuous acquisition of new knowledge and reconfiguration of competences. Several studies have found that the 'open' search strategy, i.e. the activities that firms implement to draw and re-use new knowledge from external sources, plays an important role in shaping innovative performance (Katila and Akuja, 2002; Laursen and Salter, 2004). In addition, Veugelers and Cassiman (2005) show that firms with a wider set of collaborative partners in their industry are more likely to collaborate with science, supporting the view of the importance of a firm's overall innovation search strategy for university-industry interaction.

Therefore, the following can be hypothesized.

H2. Firms which rely on external sources of information and on innovation cooperation are more likely to consider universities as an important source of knowledge.

Firm innovation can be characterized as radical or incremental. Radical innovations are breakthrough or major changes of goods and processes and are typically based on new knowledge. In contrast, incremental innovations focus on existing products, services or processes and rely upon refined or improved existing knowledge (Subramaniam and Youndt, 2005). Consequently, a lower degree of novelty of external knowledge is presumably associated with the generation of incremental innovation while a high degree of novelty should increase the probability to create radical innovation.

Previous research has shown that linking with external organizations gives the firm access to information that differs from, but can complement, its existing base of knowledge (Von Hippel, 1998; Rosenkopf and Nerkar, 2001). It is the integration of this new knowledge that leads to path-breaking innovation. Academic researchers perform a great deal of groundbreaking research and universities are regarded as sources of new knowledge. The original and technical knowledge offered by science institutions is mainly needed in innovation activities oriented towards developing new technologies and for products very new to the market. Therefore, as argued by March (1991), university knowledge is likely to be more highly valued by firms with

innovation strategies that emphasize exploration rather than exploitation. Various empirical analyses support this conclusion. For example, Monjon and Waelbroeck (2003) find that radical innovators, that is, those who come up with products new to the market, collaborate with universities, while incremental innovators benefit mostly from intra-industry knowledge spillovers. Similarly Belderbos et al. (2004) confirm that incremental innovators tend to cooperate with suppliers and customers, whereas collaborations with universities are instrumental in producing radical innovations.

These arguments lead to the following hypothesis:

H3. Firms oriented towards radical innovations, due to the basic and original nature of research performed at universities, attribute more value to academic knowledge than firms oriented towards incremental innovations.

Firms' structural differences have been identified by the economic literature as important factors in explaining the use of academic knowledge. The most frequently analyzed characteristics relate to the existing knowledge base or ability to absorb external knowledge and to the size of the firm.

The concept of absorptive capacity introduced by Cohen & Levinthal (1990) redefines the meaning of internal R&D as the ability to recognize and make use of external knowledge for commercial purposes. Absorptive capacity stresses the importance of a stock of prior knowledge to effectively absorb spillovers while cooperating, and points out that in-house technological capability is required to optimally benefit from R&D cooperation. Some studies have provided empirical evidence that absorptive capacity facilitates knowledge transfer between organizations (Mowery et al., 1996; Lane et al., 2001).

Although absorptive capacity applies to all forms of cooperation, scientific knowledge is of particular importance in interactions with universities and other research institutions. Indeed, R&D cooperation with universities is characterized by high uncertainty, high information asymmetries between partners and high transaction costs for knowledge exchange, thus requiring the presence of a strong absorptive capacity.

Drawing on these arguments, the following relationship is expected:

H4. A high level of absorptive capacity allows firms to gain more benefits, in terms of knowledge, from interactions with universities.

Firm size is also an important factor in shaping the relationships with university. Many studies have shown that firm size is positively correlated with the propensity of firms to draw university knowledge. Large firms are more likely to exploit external knowledge sources and to manage relationships with universities because they are able to dedicate greater resources and time to building links with universities compared with small firms, which may face resource constraints. Large firms are also more likely to employ staff with professional training (Laursen and Salter, 2004). Firm size may then be related to the presence of the necessary resources to efficiently implement cooperation with scientific institutions, as part of the innovation strategy of firms. However, some papers cast doubts about the positive effects of firm size on the use of external sources of information. Kleinknecht and Reijnen (1992) report that R&D cooperation is found as much among small firms as among large firms. Cohen et al. (2002) argue that while larger firms interact more with universities, smaller firms interact more efficiently. In addition, Acs et al. (1994) find that small firms' innovative activities are more responsive to university knowledge. Start-ups, for example, appear to have an edge over other firms with respect to entrepreneurial opportunity (Lee, 2000) and are often considered as a key vehicle for transferring university research into commercial innovations.

The last hypothesis may thus be formulated in the following way:

H5. The effect of firm size on the importance of academic knowledge is mixed. With the increase in size, firms draw more knowledge from universities. However, marginal benefits could be decreasing because large firms may have the resources and competencies required to perform intense in-house R&D. On the other hand, for small, young and research-active firms which may have constrained resources, the knowledge generated at universities will be of great importance.

3. Data and econometric model

3.1 Dataset

The theoretical hypotheses discussed in the previous section are tested through an econometric analysis based on the sample of firms which responded to the sixth wave of the Community Innovation Survey (CIS 2008). The CIS is a survey of innovation activities in enterprises from a range of European countries. Since 2004, the survey has been carried out every two years by Eurostat, in close cooperation with national institutes of statistics. The comparability across countries is ensured by a common survey methodology, a standard core questionnaire and a set of definitions and methodological recommendations which are mostly adopted for all countries surveyed. Although imperfect, the CIS provides a useful complement to traditional measures of innovation, such as patent statistics.

The CIS 2008 was conducted in 2009 and includes 26 EU member states: all members except Greece, as well as Iceland, Norway, Croatia and Turkey. The observation period covered by the survey is 2006-2008 inclusive i.e. from the beginning of 2006 to the end of 2008. Enterprises belonging to sections A to M of NACE Rev. 2, and with at least 10 employees, are the target population.

The sample used in the econometric analysis is based on an anonymized dataset provided by Eurostat which unfortunately is limited only to 16 countries. The list of countries considered is reported in Table 1. Only innovative firms are included in the analysis, i.e. firms that have developed a product and/or process innovation as well as firms with on-going and/or abandoned innovation activities. Other firms, lacking to filling the questions on innovation performance activities are not eligible for the present analysis. The sample includes manufacturing and service firms but does not consider firms operating in other sectors – such as construction – which generally have a lower propensity to innovate. The final sample used for the econometric estimates comprises 45,277 firms from 14 European countries.[1]

Data used to build the dependent variable and all firm-specific regressors came from the CIS 2008. The dataset was extended with country-level variables that, as it will be described further on, come from different sources.

[1] Due to the criteria used to select observations and missing values for some variables, the final sample only includes 14 of the 16 countries available. Norway and Ireland do not have any observations that meet the above mentioned criteria.

3.2 Dependent variable

We focus on the value of transferred knowledge from universities to industry and we build a variable, *Knowledge*, which measures the degree of importance of universities as a source of knowledge for the innovative activities of firms. Summary statistics for the variable are reported in Table 1.

Table 1. Importance of universities as a source of knowledge for firms' innovation activities (n=46,596)

Country	Mean	Not used (%)	Low (%)	Medium (%)	High (%)
Bulgaria	0.45	71	15.7	10.4	2.9
Cyprus	0.34	81.4	7.2	7	4.4
Czech Republic	0.68	55.9	24.3	15.6	4.2
Germany	1.02	37.8	31.2	22.2	8.8
Estonia	0.40	74.3	14.2	8.7	2.8
Spain	0.62	64	17.3	11.8	6.9
Hungary	0.97	49.5	18.1	17.8	14.6
Italy	0.45	71.1	15.9	9.3	3.7
Lithuania	0.53	68.8	13.6	13.7	3.9
Latvia	0.42	73.4	13.9	9.4	3.3
Portugal	0.64	61.1	19.4	14.1	5.4
Romania	0.59	64.2	18.1	12	5.7
Slovenia	0.79	50.2	26.1	18.2	5.5
Slovakia	0.58	63.4	19.1	13.4	4.1
Total	*0.60*	*63.4*	*18.4*	*12.5*	*5.7*

Knowledge proxies for the value that firms attribute to the flow of knowledge generated in the interaction with universities, as previously proposed by Laursen and Salter (2004). As the aim of this paper is to gain a better understanding on university-industry knowledge transfer processes, we build a firm-specific variable trying to capture the degree of importance of university as a source of knowledge from a firm's perspective. *Knowledge* has been built from a specific question that firms had to answer in the survey.

The question was so formulated: '*During the three years 2006 to 2008, how important to your enterprise's innovation activities were universities and other higher education institutions?*'. Firms had to choose between four possible answers: 'not used', if no information was obtained from universities, and 'low', 'medium' and 'high' depending on the degree of importance they attributed to universities. Hence, our dependent variable *Knowledge* is a step variable ranging between 0 and 3. It takes the value of 0 if firm does not obtain information from universities; 1 if the level of information that firm obtained is "low"; 2 if the

level of information obtained by firm is “medium” and 3 if the level of information obtained from universities is ”high”. The variable has two major advantages. Firstly, being a qualitative variable that reflects the judgment of firm’s members in the year 2009, it mitigates the endogeneity issue related to the cross-sectional nature of survey data. As noted by Mairesse and Mohnen (2010), survey data always suffers from endogeneity/simultaneity issues, making the interpretation of relationships problematic in terms of causality. Secondly, being a broad proxy of knowledge transfer between university and industry, the variable does not depend upon one specific individual knowledge transfer mechanism. University research may contribute to innovation through multiple channels and focusing only on one or few of them can yield incomplete results or, in the case of informal channels from which knowledge transfer is difficult to measure, even uncertain results. Descriptive statistics reported in Table 1 show that there is no spatial correlation among countries in explaining the importance of universities as a source of knowledge for firms’ innovation activities. On average, firms from Germany and Hungary attribute a greater importance to universities as a source of knowledge for their innovation activities. However, results depict great heterogeneity among countries. Quite surprising, in a large economy like Italy, firms attribute very low importance to universities as a source of knowledge for their innovative activities (only 3.7 percent of firms consider university as a high important source of knowledge, while more than 71 percent do not use university knowledge at all). On the other hand, the statistics report that university knowledge is highly valued by firms in some small and/or emerging European economies like Slovenia and the Czech Republic.

3.3 Independent variables

In order to test hypotheses 1a and 1b, variables related to the university system at the country level are used. The empirical literature on antecedents and indicators of entrepreneurial university is scarce. From a theoretical point of view, Institutional Economics and Resource-Based View can be used to identify the factors that affect the development of entrepreneurial universities (Guerrero and Urbano, 2010). The former approach recognizes the importance of environmental or institutional factors while the latter approach emphasizes the importance of resources and capabilities internal to universities. With the present analysis centered on the macro-factors that could foster the transfer of knowledge from university to industry, three variables in line with the Institutional perspective are included in the model: *Patents* and *GERD business-*

university, which proxy for the entrepreneurial orientation of a university research system, and *Citations*, which accounts for the quality of scientific base as a whole. The variable *Patents* has been built as the ratio between the number of patent applications from the higher education sector and the total number of patent applications at the country level. The variable measures the weight of university patenting on the total patenting activity of a country. In the sample, 7 percent of total patenting comes from universities. Several studies have highlighted that patents are a proxy of research activity in industrially relevant fields of science and that high levels of research productivity, in terms of patents, can be associated with the degree of entrepreneurial activities of a university (i.e. Van Looy et al., 2011). Therefore, patenting activity can be considered as an indicator of entrepreneurial orientation.

The second country specific variable is *GERD business-university* which measures the share of university R&D funded by the business enterprise sector.[2] Summary statistics reported in Table 2 show that, on average, only 2 percent of university R&D is funded by the business sector. This indicates that scientific and industrial research have very weak ties in the European context.

To account for the quality and strength of the scientific research of a country, the model includes the variable *Citations*. The variable represents the indicator '*Citations per faculty*' computed by Quacquarelli Symonds (QS) in the QS World University Rankings 2008 for Europe.[3] The indicator refers to the total number of citations of published research for a five-year period divided by the number of academicians in a university. For the calculation of the '*Citations per faculty*' QS uses data from Scopus, the world's largest abstract and citation database of peer-reviewed literature. Such an indicator is the best understood and most widely accepted measure of research strength and quality. Both previous variables, i.e. *GERD business-university* and *Citations*, have been used by Tijssen (2006) as determinants of university entrepreneurialism.

[2] For *Patents* and *GERD business-university* the source of data is Eurostat and 2006 is the reference year.

[3] Quacquarelli Symonds (QS) is a British company specialized in education and study abroad. The company releases annual university rankings to compare the world's top universities. Today, the rankings are known as the QS World University Rankings and are considered as one of the three most influential university rankings in the world, along with the Times Higher Education World University Rankings and the Academic Ranking of World Universities.

All other hypotheses are tested by means of regressors at the firm level. The importance of universities as a source of knowledge for firms' innovative activities depends not only on the institutional and macroeconomic context, but also on several micro-factors. Therefore, to avoid that country-level covariates simply capture firms' evaluation on the importance of university knowledge for their R&D activities, we use a broad set of covariates reflecting firms' characteristics and strategies. In order to test H2, the model is extended with two proxies for the 'openness' of a firm's innovation search strategy. *Openness* is computed in accordance with Laursen and Salter (2004) and reflects the propensity of a firm to rely on external sources of knowledge. The question used to construct the dependent variable also provides information on other sources of knowledge. To construct *Openness*, internal sources, i.e. 'enterprise' and 'enterprise group', and 'universities or other higher education institutions' are excluded, while each of the remaining external sources of knowledge are coded as a binary indicator with the value of 0 for the answer 'not used' and the value of 1 for all of the other answers. These indicators are summed to make the *Openness* variable which, ranges between 0, for firms that do not use external sources of knowledge, and 8, for firms that use all possible external sources listed in the question. The assumption is that firms oriented toward more open search strategies use a higher number of sources. Descriptive statistics show that firms use on average 4 different sources of external knowledge (the mean of *Openness* is 4.96) suggesting that searching for external knowledge is a well-defined strategy of firms.

The second variable capturing firms' openness toward search strategies is *Cooperation.* It uses the question '*During the three years 2006-2008, did your enterprise co-operate on any of your innovation activities with other enterprises or institutions?*' and is a proxy for the propensity of firms to engage in active innovation cooperation with various partners. The variable is constructed similarly to *Openness* and it is a count variable for the various types of partners which respondent firms cooperated with. While *Openness* can be considered as a proxy for knowledge spillovers, *Cooperation* is more closely linked to firms' cooperation strategy.

To proxy for the type of innovations developed by firms, distinguishing between radical and incremental, we built two binary indicators. *Product mkt* and *Process mkt* are binary variables equal to 1 for firms introducing product (goods/services) or process innovations that are new to the market, i.e. that are not

already available in the market from competitors, and 0 for firms with product and process innovations only new for the firms themselves. Both variables are considered as proxies for radical innovations and are used to test hypothesis 3. In our sample the percentage of radical innovators (34) is higher than incremental innovators (only 12 percent of firms).

The model further includes various structural factors to test hypothesis 4 and 5. Absorptive capacity refers to technological capabilities of firms and is measured as the ratio between in-house R&D expenditures and the total market sales of good and services (*Absorptive capacity*). The data show a weak propensity of European firms to invest in internal R&D. On average, the expenditure for in-house R&D is only 5 percent of the annual turnover and almost half of the firms included in the sample do not perform in-house R&D. Firm size is proxied by the total turnover in thousands of Euro (*Size*) and, in order to test H5, the variable is also included squared (*Size squared*). In addition, *Small young* is a dummy variable equal to 1 for small, young and research-active firms. CIS data do not provide direct information to identify such firms so the following procedure is used. A firm is considered small if its annual turnover is less than 50 million Euro. Information on total sales are also used to estimate firm age: firms that declare a turnover equal to 0 in the base year of the survey (2006) and a turnover different to 0 in the last year of the survey (2008) are considered as young. The underlying assumption is that such firms rise, or begin their activity, after 2006. Lastly, firms who spend resources on internal R&D are considered as being research-active.

Finally, the following control variables are considered in the analysis. To take sectorial specificities into account, the model is extended with *High tech* and *Knowledge intensive*, two binary variables that, according to the classification adopted by Eurostat and OECD, identify respectively firms from high-technology as well as medium-high-technology industries, and knowledge-intensive services. To control for firms ability to compete on the foreign market the dummy variable *Export* is built. The variable equals to 1 for firms exporting their goods and services and to 0 for other firms. Due to the strong competition that characterizes the international market, exporting firms have been found to innovate more and to rely more on universities than other firms (Altomonte et al., 2013; Bratti and Felice, 2011). The last control refers to the protection of intellectual and property rights at aggregate country-level (*Protection*). Unfortunately, CIS 2008 does not

provide information on this important aspect for knowledge transfer. Thereby, we rely on the indicator provided by Economic Freedom of the World. Such indicator is computed at country level as the average of firms' perception on the effectiveness of their national legal system in protecting intellectual and property rights.

Table 2. Descriptive statistics and correlations

	Mean	Std. Dev.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Firm-specific variables																		
(1) Openness	4.96	2.56	0	8	1.00													
(2) Cooperation	0.71	1.38	0	6	0.30	1.00												
(3) Product mkt	0.34	0.47	0	1	0.21	0.22	1.00											
(4) Process mkt	0.12	0.32	0	1	0.10	0.17	0.22	1.00										
(5) Absorptive capacity	0.05	1.06	0	0.73	0.00	0.01	-0.00	-0.00	1.00									
(6) Size	52.6	462.7	0	39081	0.06	0.11	0.05	0.05	-0.00	1.00								
(7) Small young	0.01	0.11	0	1	0.02	0.01	0.00	-0.03	0.05	-0.01	1.00							
(8) Export	0.57	0.50	0	1	0.14	0.13	0.15	0.03	-0.00	0.04	-0.00	1.00						
(9) High tech	0.24	0.43	0	1	0.08	0.06	0.11	0.00	-0.00	0.02	0.01	0.25	1.00					
(10) Knowledge intensive	0.21	0.40	0	1	0.04	0.10	0.05	0.00	-0.00	0.02	0.04	-0.13	-0.28	1.00				
Country variables																		
(11) Citations	4.77	2.41	0	7.61	0.02	-0.10	0.05	0.00	-0.00	0.06	0.04	0.01	0.02	0.01	1.00			
(12) GERD business-university	0.02	0.02	0.00	.06	-0.01	-0.04	-0.08	-0.21	-0.00	0.04	0.07	0.08	0.08	0.04	0.28	1.00		
(13) Patents	0.07	0.07	0.02	0.28	0.02	0.10	-0.03	0.05	0.00	-0.04	-0.00	0.09	-0.04	0.03	-0.46	-0.22	1.00	
(14) Protection	6.00	1.04	3.8	8.3	0.03	0.02	-0.03	-0.07	0.00	0.04	0.06	0.13	0.04	0.05	0.45	0.47	0.24	1.00

3.4 Econometric model

Since the dependent variable is a multinomial-choice with a logical order (the values of *Knowledge* range between 0 and 3), an ordered logit model (OLM) is estimated. The model estimates the probability that universities are an important source of knowledge for firms as a function of the covariates. In Table 3 below the coefficients are in log-odds ratio form and the standard interpretation is that, for a one unit increase in a regressor, the dependent variable level is expected to change by its respective regression coefficient in the ordered log-odds scale, holding other regressors constant. Looking for example at column 1, a unit increase in the openness variable increases the log-odds to be in the category of high importance by 0.67. The coefficients in this model are, in any case, difficult to interpret and the analysis will mainly concentrate on the sign and statistical significance of the coefficients.[4] The maximum likelihood method is used to estimate the model parameters.

4. Findings

The empirical analysis aims at testing whether universities with an entrepreneurial orientation enhance the value of knowledge transferred to industry and which factors affect the importance of academic knowledge for firms' innovative activities. The discussion of the findings begins with the analysis of the OLM estimates summarized in Table 3. In order to discern the importance of university knowledge transfer to industry, distinguishing between institutional and/or individual factors, the research hypotheses developed in section 2 are tested step-by-step. In column (1) only variables referring to environmental and institutional context are considered. As the literature has highlighted the relevance of firms' strategies and characteristics in shaping the links with university, column (2) assess the impact of such micro-factors on the importance attributed to university knowledge. Finally in column (3), an integrated approach that simultaneously considers both demand-side factors for knowledge, captured at firm-level, and supply-side factors, captured at country-level, is presented.

[4] With ordinal dependent variables, the assumptions of ordinary least square estimator are violated (normality and homoscedasticity of error term) which can lead to incorrect inferences. Ordered logit and ordered probit models provide consistent estimates. For more details, see Greene (2008).

Table 3. Ordered logit estimates explaining the importance of universities as a source of knowledge

	(1)	(2)	(3)
Openness		0.67***	0.66***
		(0.05)	(0.05)
Cooperation		0.19***	0.20***
		(0.26)	(0.02)
Product mkt		0.06**	0.08**
		(0.03)	(0.03)
Process mkt		0.06	0.10
		(0.09)	(0.07)
Absorptive capacity		0.03***	0.03***
		(0.01)	(0.01)
Size		0.24***	0.19***
		(0.05)	(0.07)
Size squared		-0.01***	-0.01**
		(0.00)	(0.00)
Small young		0.26***	0.14***
		(0.06)	(0.04)
Export		0.18***	0.16***
		(0.05)	(0.04)
High tech		0.39***	0.28**
		(0.13)	(0.11)
Knowledge intensive		0.48***	0.44***
		(0.05)	(0.04)
Citations	0.04***		0.06***
	(0.00)		(0.17)
GERD business-university	14.33***		23.65***
	(1.19)		(2.07)
Patents	0.45*		1.44**
	(0.25)		(0.66)
Protection	-0.07		-0.27
	(0.05)		(0.22)
Observations	45277	45277	45277
Pseudo R2	0.05	0.20	0.2243
Log likelihood	-47394	-36.153	-35861

Notes: ***, **, * indicate that coefficients are statistically significant at the 1,5 and 10% level. Coefficients are in log-odds ratio form. Ancillary parameters are not reported. Standard errors clustered at country level are shown in parentheses.

Empirical results of specification (1) show that firms consider universities a more important source of knowledge in countries where universities have higher entrepreneurial orientation. Increasing shares of R&D activities funded by business sectors (*GERD business-university*) and the patenting activity of a national university system (*Patents*) enhance the value of knowledge transferred to industry. A unit increase in the *GERD business-university* and *Patents* variables increases the log-odds that firms consider university knowledge as being very important for their innovative activities by 14.33 and 0.45. The quality of academic research (*Citations*) is also associated with high-valued knowledge flows from university to industry. Such

findings are consistent with theoretical frameworks that emphasize the relevance of environmental and institutional conditions in fostering university-industry linkages and provide empirical support to our main hypotheses (H1a and H1b). Hence, the characteristic of the overall research university system seems to determine the importance of academic knowledge transferred to firms.

In column (2), the hypotheses related to firms' characteristics and strategies for innovation are tested. The coefficients on the variables capturing firms 'openness' towards innovation search strategies, namely *Openness* and *Cooperation*, are positive and statistically significant. This means that the extent to which firms benefit from university knowledge is shaped by the internal strategies for knowledge exploitation and exploration. Indeed, firms oriented toward open search strategies and with various types of cooperative partners have a higher propensity to recognize universities as a source of knowledge for their innovative activities. Hence, firms that rely on external sources of information and on innovation cooperation are more likely to consider universities as an important source of knowledge. A plausible explanation is that scientific institutions offer new technical knowledge which is mainly needed in innovation activities oriented towards developing new technologies and for products very new to the market. These findings provide support to Hypothesis 2 and are in line with Katila and Akuja (2002) and Laursen and Salter (2004). The authors found that the research strategy of firms plays an important role in shaping innovative performance and indicates that universities are a part of the overall strategy for searching and exploring new knowledge.

In regard to Hypothesis 3, concerning the higher value attributed to academic knowledge by radical innovators rather than incremental innovators, the evidence is mixed. The positive coefficient of *Product mkt*, the proxy for firms' ability to introduce products new to the market, means that radical innovators are more likely to benefit from information generated from universities than other companies. Such an effect is robust for firms that have the ability to introduce new innovative goods or services, whereas it is not statistical significant for firms' ability to introduce innovative processes not available from the competitors in the market (*Process mkt*).

The estimates confirm the importance of structural factors in explaining why some firms draw more from universities. In line with existing studies, the variable *Absorptive capacity* shows a positive and statistically significant coefficient, indicating that, on average, a higher level of in-house R&D expenditures allows firms to gain more benefits from interactions with universities in terms of knowledge. This finding seems to validate Hypothesis 4 on firms' effectiveness to draw from universities. A possible explanation is that firms prefer to invest in internal R&D rather than buying research outputs from outside in order to increase their absorptive capacity. This, in turn, implies a greater ability to internalize external knowledge and encourages firms to establish relationships with external partners.

Finally, the empirical evidence on the effect of firm size is mixed. The average effect of the coefficient capturing a firm´s size (*Size*) is positive and statistically significant. This means that as firms increase in size they draw more knowledge from universities. However the negative coefficient for *Size squared* indicates that with the increase of firm size, the value attributed to university knowledge increases less than proportionally. Hence the linear and quadratic terms of firm size indicate a positive relationship, but with diminishing returns, with the importance of university as a source of knowledge, and suggest the presence of an inverted U-shaped relation between the two variables. On the other hand, the variable *Small young* is positive and statistically significant, showing that small, young and research-active firms place the highest value on academic knowledge and gain the greatest benefits from interactions with universities. Such findings are consistent with Hypothesis 5. A possible explanation is that large firms are, in general, more likely to draw form universities; however, with firm size above a certain threshold, the value of knowledge acquired from external sources is only a complement of knowledge generated with internal resources. Instead, for small and young innovative firms, knowledge spillovers from universities are the key driver of their innovation activities.

The controls show that firms belonging to high technology and knowledge intensive sectors as well as more export oriented firms seem to draw more from universities in their innovative activities. Such results are consistent with the previous literature. Lastly, the variable *Protection* has a negative sign but is not statistically significant. Therefore, the analysis does not find evidence that appropriation conditions affect the

value that firms place at university knowledge. A possible explanation relies on the fact that firms and universities are non-competition since they do not compete in the market but enhance their own respective skills (Huang and Yu, 2011). In addition, the more generic nature of research projects with universities should involve less appropriation issues as compared to the more commercially sensitive cooperation with customers/suppliers or competitors.

Finally, column (3) reports the results of the more comprehensive specification that includes both firm-level and country-level variables. With respect to the previous model specifications, the sign and the statistical significance of the coefficients are unchanged, and the magnitude of the point estimates is very similar also.

4.1 Robustness

In this section, the robustness of the ordered logit estimates is tested. The check relates to the proportional odds assumption underlining the OLM, i.e. the equality of the slope coefficients across each category of the dependent variable.

4.1.1 Generalized ordered logit model

The ordered logit model is equivalent to $j-1$ binary regressions, where j refers to the categories of the dependent variable. A critical assumption of the model is that the slope coefficients are identical across each regression (the proportional odds assumption). To test this hypothesis in our sample we use a Wald test by Brant (1990) to determine whether the coefficients for some independent variables differ across the binary equations defined by whether the outcome y is greater than or equal to j. The test statistics, not shown here to save space, indicate that the assumption is violated for the following variables: *Openness*, *Cooperation*, *Absorptive capacity*, *Size*, *Small young*, *Export*, *High tech*, *Citations* and *GERD business-university*.

Then, we provide a robustness check for our model providing additional estimates with a generalized ordered logit model (GOLM) which allows for different estimates of coefficients across binary equations for the variables that violate the proportional odds assumption. Such a model is less restrictive than OLM, which

assumes proportional odds among the categories of the dependent variable, but is more parsimonious and interpretable than non-ordinal methods.

GOLM has been regressed on our full specification tabulated in Table 3 - column (3) where it provides an integrated approach that simultaneously considers both supply-side and institutional characteristics factors. Table 4 provides the estimates for each of the binary models: column (1) contrasts firms with dependent variable equal to 0, i.e. firms that not obtain information form universities, with firms having dependent variable greater than 0; column (2) contrasts firms with dependent variable equal to 0 or 1 with firms having dependent variable equal to 2 or 3; column (3) contrasts firms with dependent variable less than 3, with firms having dependent variable equal to 3, i.e. firms with that place the highest value on university knowledge.

All of results obtained by OLM seem to be confirmed. GOLM estimates confirm the role of universities to determine the value of scientific knowledge for industry and in explaining cross-national disparities, in particular of those universities located in countries with both higher entrepreneurial orientation and quality of academic research, providing again empirical support to theoretical frameworks that emphasize the relevance of environmental and institutional conditions in fostering university-industry linkages. Findings hold also in regard to demand-side factors. In particular, findings confirm that firms, relying broadly on external sources of information, on innovation cooperation and inclined towards more radical product/process innovations, place higher value on academic knowledge.

More interestingly, GOLM estimates provide further support for the inverter U-shaped relationship hypothesized between firm size and value of academic knowledge. Indeed the coefficient of *Size* is positive and statistically significant in column (1) and (2), but in not statistically different from 0 in column (3). This means that with the increase of firm size, the probability that firms consider university knowledge of low or medium importance (but not of high importance) also increases.

Table 4. Generalized ordered logit estimates explaining the importance of universities as a source of knowledge

	(1)	(2)	(3)
Openness	0.73***	0.52***	0.38***
	(0.05)	(0.05)	(0.05)
Cooperation	0.18***	0.24***	0.26***
	(0.03)	(0.03)	(0.02)
Product mkt	0.07**	0.07**	0.07**
	(0.03)	(0.03)	(0.03)
Process mkt	0.10	0.10	0.10
	(0.07)	(0.07)	(0.07)
Absorptive capacity	0.02***	0.03***	0.03***
	(0.00)	(0.00)	(0.01)
Size	0.84***	0.19***	0.05
	(0.18)	(0.05)	(0.05)
Size squared	-0.07***	-0.00***	-0.00
	(0.01)	(0.00)	(0.00)
Small young	0.18***	0.11***	0.18***
	(0.07)	(0.03)	(0.05)
Export	0.17***	0.16***	0.05
	(0.04)	(0.05)	(0.05)
High tech	0.35***	0.24**	0.10*
	(0.13)	(0.12)	(0.06)
Knowledge intensive	0.45***	0.45***	0.45***
	(0.04)	(0.04)	(0.04)
Citations	0.06***	0.05**	0.06*
	(0.02)	(0.02)	(0.04)
GERD business-university	24.95***	24.11***	26.68***
	(2.50)	(2.26)	(4.32)
Patents	1.53**	1.53**	1.53**
	(2.26)	(2.26)	(2.26)
Protection	-0.29	-0.29	-0.29
	(0.23)	(0.23)	(0.23)
Observations	45227		
Pseudo R2	0.24		
Log likelihood	-35006		

Notes: ***, **, * indicate that coefficients are statistically significant at the 1,5 and 10% level. Coefficients are in log-odds ratio form. Ancillary parameters are not reported. Standard errors clustered at country level are shown in parentheses.

5. Conclusions

Knowledge generating institutions are considered as crucial sources of information for firm innovation. The economic literature has largely explored the exchange of knowledge between university and industry, with a particular focus on the determinants of R&D cooperation. Unlike most of the previous research, the present paper concentrates on the factors that affect the importance of academic knowledge for firms' innovative activities and therefore pays special attention to the effectiveness of university-industry interactions rather than to their probability. An empirical approach that simultaneously considers both demand-side factors for university knowledge, i.e. related to industry, and supply-side factors, i.e. related to university, is adopted. The latter factors are captured by firms' structural variables and strategy for innovation while the former are captured by characteristics of national research systems. Such an approach leads to a comprehensive analysis of the topic and is particular useful to highlight cross-national disparities in the importance of universities for firms' innovation. The econometric analysis is conducted on a large sample of manufacturing and services European firms derived from the Community Innovation Survey 2008.

In line with previous studies, the research confirms the important role of firms' structural characteristics and managerial choices in influencing the value of knowledge generated at university. Firms operating in knowledge intensive sectors, with internal R&D efforts and oriented towards open search strategies and radical innovation consider universities as important sources of knowledge. On the other hand, the relationship between firm size and the importance of university knowledge appears more complex than normally shown in the previous literature. Overall, with the increase of firm size the value of academic knowledge increases too. However, the marginal benefit is decreasing and the highest value is perceived by small, young and research-active firms. In light of these findings, cross-country differences in the importance of university knowledge for firms' innovation can certainly be explained by the industrial structure of the national economy and by search and cooperation strategies of firms.

In addition to previously studied factors, the paper shows that also the characteristics of national innovation systems play an important role in determining the value of scientific knowledge for firms' innovation. In particular, the econometric analysis suggests that the effectiveness of academic knowledge in supporting

firms' innovative activities is positively affected by the entrepreneurial orientation of universities and by the quality of university research.

Such results contribute to explain cross-country disparities in university-industry interactions among European countries and indicate that innovation systems based on the entrepreneurial role of university are of great importance for generation and dissemination of scientific knowledge and, in turn, for regional/national economic competitiveness and development. This has important implications for policy makers. As Payumo et al. (2003) demonstrate, pursuing the objective of becoming an entrepreneurial university requires a national legal framework, a research budget and the right mix of policies, people and processes. Accordingly, governments may need to stimulate entrepreneurship education and encourage the development of entrepreneurial universities.

A limitation of this study is related to the cross-sectional structure of the data. Since most of the explanatory variables are contemporaneous with the phenomenon that they intend to explain, that is, the importance of university knowledge for firm innovation, one has to be cautious in interpreting the results in terms of causal relationships between variables. As further interesting step, the empirical analysis should be extended to include additional countries like the US or Japan, that is, countries which Europe lags behind in regards to university-industry interactions.

References

Acs, Z.J., Audretsch, D.B., Feldman, M.P. (1994). R&D spillovers and recipient firm size. *Review of Economics and Statistics*, 76, 336-340.

Altomonte, C., Aquilante, T., Bekes, G., Ottaviano, G. (2013). Internationalization and innovation of firms: evidence and policy. *Economic Policy*, 28(76), 663-700.

Audretsch, D.B., Leyden, D.P., Link, A.N. (2013). Regional Appropriation of Univesity-Based Knowledge and Technology for Economic Development. University of North Carolina Working Paper.

Azagra-Caro, J.M. (2007). What Type of Faculty Member Interacts with what Type of Firm? Some Reasons for the Delocalisation of University-Industry Interaction. *Technovation*, 27(11), 704-715.

Bekkers, R., Bodas Freitas, I.M. (2008). Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? *Research Policy*, 37(10), 1837-1853.

Belderbos, R., Carree, M., Lokshin, B. (2004). Cooperative R&D and Firm Performance. *Research Policy*, 33(10), 1477-92.

Bercovitz, J., Feldmann, M. (2006). Entpreprenerial Universities and Technology Transfer: A Conceptual Framework for Understanding Knowledge-Based Economic Development. *Journal of Technology Transfer*, 31, 175-188.

Bergmam, E.M. (2010). Knowledge links between European Universities and firms: A review. *Paper in Regional Science*, 89(2), 311-333.

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

Bratti, M., Felice, G. (2011). Are exporters more likely to introduce product innovations? Centro Studi Luca D'Agliano Working Papers.

Caldera, A., Debande, O., (2010). Performance of Spanish universities in technology transfer: An empirical analysis. *Research Policy*, 39(9), 1160-1173.

Chesbrough, H.W. (2003). Open Innovation: The new imperative for creating and profiting from technology, Boston: Harvard Business School Press.

Clark, B.R., (1998). Creating Entrepreneurial Universities: Organisational Pathways of Transformation. Pergamon/Elsevier Science, Oxford.

Cohen W.M., Levinthal, D.A. (1990). Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly*, 35, 128-152.

Cohen, W.M., Nelson, R.R., Walsh, J.P. (2002). Links and impacts: The influence of public research on industrial R&D. *Management Science*, 48(1), 1-23.

D'Este, P., Patel, P. (2007). University-Industry Linkages in the UK: What are the Factors Underlying the Variety of Interactions with Industry? *Research Policy*, 36(9), 1295-1313.

D'Este, P., Perkmann, M. (2011). Why do academics engage with industry? The entrepreneurial university and individual motivations. *Journal of Technology Transfer*, 36, 316-339.

Etzkowitz, H. (1983). Entrepreneurial Scientists and Entrepreneurial Universities in American Academic Science. *Minerva* 21, 1-21.

Etzkowitz, H., Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations. *Research Policy*, 29, 109-123.

Etzkowitz, H., Webster, A., Gebhardt, C., Terra, B. (2000). The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm. *Research Policy*, 29(2), 313-330.

Economic Policy Committee, DG ECFIN, Working group in Research and Development (2002). Report on Research and Development. Brussels.

Feller, I. (1990). Universities as engines of R&D-based economic growth: They think they can. *Research Policy*, 19(4), 335-348.

Fontana, R., Geuna, A., Matt, M. (2006). Factors affecting university–industry R&D projects: The importance of searching, screening and signaling. *Research Policy*, 35, 309-323.

Friedman, J., Silberman, J. (2003). University Technology Transfer: Do Incentives, Management, and Location Matter?. *Journal of Technology Transfer*, 28, 17-30.

Geuna, A., Muscio, A. (2009). The governance of university knowledge transfer: A critical review of the literature. *Minerva: A review of Science, Learning and Policy*, 47(1), 423-434.

Greene, W.H. (2008). Econometric analysis. 6th ed., Upper Saddle River, New Jersey, Prentice Hall.

Griliches, Z. (1998). R&D and Productivity. Chicago University Press.

Guerrero, M., Urbano, D. (2010). The development of an entrepreneurial university. *Journal of Technology Transfer*, 37(1), 43-74.

Huang, K.F., Yu, C.M. (2011). The effect of competitive and non-competitive R&D collaboration on firm innovation. *Journal of Technology Transfer*, 36(4), 383–403.

Jaffe, A. (1989). Real effects of academic research. *American Economic Review*, 79, 957-970.

Katila, R., Ahuja, G. (2002). Something old, something new: a longitudinal study of search behaviour and new product introduction. *Academy of Management Journal*, 45, 1183-1194.

Kleinknecht, A., Mohnen, P. (2002). Innovation and Firm Performance. Econometric Explorations of Survey Data. Palgrave, New York.

Kleinknecht, A., Reijnen, J.O. (1992).Why do firms cooperate on R&D? an empirical study. *Research Policy*, 21(4), 347-360.

Klevorick, A.K., Levin, R.C., Nelson, R.R., Winter, S. G. (1995). On the sources and significance of interindustry differences in technological opportunities. *Research Policy*, 24, 185-205.

Landry, R., Saihi, M., Amara, N., Ouimet, M. (2010). Evidence on how academics manage their portfolio of knowledge transfer activities. *Research Policy*, 39(10), 1387-1403.

Lane, P.J., Salk, J.E., Lyles, M.A. (2001). Absorptive capacity, learning, and performance in international joint ventures. *Strategic Management Journal*, 22, 1139-1161.

Laursen, K., Salter, A. (2004). Searching high and low: what type of firms use universities as a source of innovation? *Research policy*, 33, 1201-1215.

Lee, Y.S. (2000). The sustainability of university-industry research collaboration: an empirical assessment. *Journal of Technology Transfer*, 25(2), 111-133.

Lehrer, M., Nell, P., Garber, L. (2009). A national systems view of university entrepreneurialism: Inferences from comparison of the German and US experience. *Research Policy*, 38(2), 268-280.

Link, A.N., Siegel, D.S., Bozeman, D. (2007). An empirical analysis of the propensity of academics to engage in informal university technology transfer. *Industrial and Corporate Change*, 16(4), 641-655.

Mansfield, E. (1991). Acedemic research and industrial innovation. *Research Policy*, 20, 1-12.

Mansfield, E. (1995). Academic research underlying industrial innovations: sources, characteristics, and financing. *The Review of Economics and Statistics*, 77(1), 55-65.

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

March, J.G. (1991). Exploration and Exploitation in Organizational Learning. *Organization Science*, 2(1), 71-87.

Mairesse, J., Mohnen, P. (2010). Using innovation surveys for econometric analysis. NBER Working Paper No. 15857.

Martinelli, A., Meyer, M., von Tunzelmann, N. (2008). Becoming an entrepreneurial university? A case study of knowledge exchange relationships and faculty attitudes in a medium-sized, research-oriented university. *Journal of Technology Transfer*, 33, 259-283.

Mathieu, A. (2011). University-Industry interactions and knowledge transfer mechanisms: a critical survey. CEB Working Paper 11/015.

Mavi, R.K. (2014). Indicators of Entrepreneurial University: Fuzzy AHP and Fuzzy TOPSIS Approach. *Journal of the Knowledge Economy*, 5(2), 370-387.

Meyer-Krahmer, F., Schmoch, U. (1998). Science-based technologies: University-industry interactions in four fields. *Research Policy*, 27(8), 835-851.

Monjon, S., Waelbroeck, P. (2003). Assessing Spillovers from Universities to Firms: Evidence from French Firm-Level Data. *International Journal of Industrial Organization*, 21(9), 1255-1270.

Mowery, D.C., Oxley, J.E., Silverman, B.S. (1996). Strategic alliances and interfirm knowledge transfer. *Strategic Management Journal*, 17, 77-92.

Mueller, P. (2006). Exploring the knowledge filter: How entrepreneurial and university-industry relationships drive economic growth. *Research Policy*, 35(10), 1499-1508.

Narin, F., Hamilton, K, Olivastro D. (1997). The Increasing Linkage between US Technology and Public Science. *Research Policy*, 26, 317-330.

Owen-Smith, J., Riccaboni, M., Pammolli, F., Powell, W.W. (2002). A comparison of US and European University-industry relations in the life sciences. *Management Science*, 48, 24-43.

Payumo, J.G., Arasu, P., Fauzi, A.M., Siregar, I.Z., Noviana, D. (2013). An entrepreneurial, research-based university model focused on intellectual property management for economic development in emerging economies: the case of Bogor Agricultural University. *World Patent Information*, 36, 22-31.

Petruzzelli, A.M. (2011). The impact of technological relatedness, prior ties, and geographical distance on university-industry collaborations: A joint-patent analysis. *Technovation*, 31(7), 309-319.

Rothaermel, F.T., Agung, S.D., Jiang, L. (2007). Entrepreneurial activities at universities: past research, current state, and future directions. *Industrial and Corporate Change*, 16(4), 691–791.

Rosenkopf, L., Nerkar, A. (2001). Beyond local search: Boundary-spanning, exploration, and impact in the optical disk industry. *Strategic Management Journal*, 22(4), 287-306.

Santoro, M.D., Bierly, P.E. (2006). Facilitators of Knowledge Transfer in University-Industry Collaborations: A Knowledge-Based Perspective. *IEEE Transactions on Engineering Management*, 53(4), 495-507.

Schartinger D., Schibany A., Gassler, H. (2001). Interactive Relations between Universities and Firms: Empirical Evidence for Austria. *Journal of Technology Transfer*, 26, 255-268.

Shan, W., Walker, G., Kogut, B. (1994). Interfirm cooperation and startup innovation in the biotechnology industry. *Strategic Management Journal*, 15, 387-394.

Siegel, D., Waldman, D.A., Atwater, L.E., Link, A.N. (2003). Commercial knowledge transfers from universities to firms: improving the effectiveness of university-industry collaboration. *Journal of High Technology Management Research*, 14, 111-133.

Siegel, D., Waldman, D., Link, A.N. (2003). Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study. *Research Policy*, 32, 27-48.

Srholec, M. (2014). Understanding the diversity of cooperation on innovation across countries: multilevel evidence from Europe. *Economics of Innovation and New Technology*, 1, 1-24.

Stuart, T.E., Ozdemir, S.Z., Ding, W.W. (2007). Vertical alliance networks: The case of university-biotechnology-pharmaceutical alliance chains. *Research Policy*, 36, 477-498.

Subramaniam, M., Youndt, M.A. (2005). The Influence of Intellectual Capital on the Types of Innovative Capabilities. *Academy of Management Journal*, 48 (3), 450-463.

Tijssen, R.J. (2006). Universities and industrially relevant science: Towards measurement models and indicators of entrepreneurial orientation. *Research Policy*, 35, 1569-1585.

Yli-Renko, H., Autio, E., Sapienza, H.J. (2001). Social capital, knowledge acquisition, and knowledge exploitation in young technology-based firms. *Strategic Management Journal*, 22, 587-613.

Van Looy, B., Landoni, P., Callaert, J., van Pottelsberghe, B., Spasalis, E., Bedackere, K. (2011). Entrepreneurial effectiveness of European universities: An empirical assessment of antecedents and trade-offs. Research Policy, 40, 553-564.

Van Oort, F.G., Burger, M.J., Knoben, J., Raspe, O. (2012). Multilevel approaches and the firm-agglomeration ambiguity in economic growth studies. Journal of Economic Surveys, 23(3), 468-491.

Van Wijk, R., Jansen, J.J., Lyles, M.A. (2008). Inter- and Intra-Organizational Knowledge Transfer: A Meta-Analytic Review and Assessment of its Antecedents and Consequences. *Journal of Management Studies*, 45(4), 830-853.

Veugelers, R., Cassiman, B. (2005). R&D cooperation between firms and universities. Some empirical evidence from Belgian manufacturing. *International Journal of Industrial Organization*, 23, 355-379.

Veugelers, R., Del Rey, E. (2014). The contribution of universities to innovation, (regional) growth and employment. EENEE Analytical Report No. 18.

Von Hippel, E. (1998). Economics of product development by users: The impact of sticky local information. *Management Science*, 44(5), 629-644.

IAW-Diskussionspapiere

Die IAW-Diskussionspapiere erscheinen seit September 2001. Die vollständige Liste der IAW-Diskussionspapiere von 2001 bis 2011 (Nr. 1-84) finden Sie auf der IAW-Internetseite http://www.iaw.edu/index.php/IAW-Diskussionspapiere.

IAW-Diskussionspapiere seit 2011:

Nr. 85 (Juni 2012)
From the Stability Pact to ESM – What next?
Claudia M. Buch

Nr. 86 (Juni 2012)
The Connection between Imported Intermediate Inputs and Exports: Evidence from Chinese Firms
Ling Feng / Zhiyuan Li / Deborah L. Swenson

Nr. 87 (August 2012)
EMU and the Renaissance of Sovereign Credit Risk Perception
Kai Daniel Schmid / Michael Schmidt

Nr. 88 (September 2012)
The Impact of Random Help on the Dynamics of Indirect Reciprocity
Charlotte Klempt

Nr. 89 (Oktober 2012)
Specific Measures for Older Employees and Late Career Employment
Bernhard Boockmann / Jan Fries / Christian Göbel

Nr. 90 (Oktober 2012)
The Determinants of Service Imports: The Role of Cost Pressure and Financial Constraints
Elena Biewen / Daniela Harsch / Julia Spies

Nr. 91 (Oktober 2012)
Mindestlohnregelungen im Maler- und Lackiererhandwerk: eine Wirkungsanalyse
Bernhard Boockmann / Michael Neumann / Pia Rattenhuber

Nr. 92 (Dezember 2012)
Turning the Switch: An Evaluation of the Minimum Wage in the German Electrical Trade Using Repeated Natural Experiments
Bernhard Boockmann / Raimund Krumm / Michael Neumann / Pia Rattenhuber

Nr. 93 (Januar 2013)
Outsourcing Potentials and International Tradability of Jobs
Evidence from German Micro-Level Data
Tobias Brändle / Andreas Koch

Nr. 94 (Februar 2013)
Firm Age and the Demand for Marginal Employment in Germany
Jochen Späth

Nr. 95 (Juli 2013)
Messung von Ausmaß, Intensität und Konzentration des Einkommens- und Vermögensreichtums in Deutschland
Martin Rosemann / Anita Tiefensee

Nr. 96 (Oktober 2013)
Flexible Collective Bargaining Agreements: Still a Moderating Effect on Works Council Behaviour?
Tobias Brändle

Nr. 97 (Oktober 2013)
New Firms and New Forms of Work
Andreas Koch / Daniel Pastuh / Jochen Späth

Nr. 98 (November 2013)
Non-standard Employment, Working Time Arrangements, Establishment Entry and Exit
Jochen Späth

IAW-Diskussionspapiere

Nr. 99 (Dezember 2013)
Intraregionale Unterschiede in der Carsharing-Nachfrage – Eine GIS-basierte empirische Analyse
Andreas Braun / Volker Hochschild / Andreas Koch

Nr. 100 (Dezember 2013)
Changing Forces of Gravity: How the Crisis Affected International Banking
Claudia M. Buch / Katja Neugebauer / Christoph Schröder

Nr. 101 (Januar 2014)
Vertraulichkeit und Verfügbarkeit von Mikrodaten
Gerd Ronning

Nr. 102 (Januar 2014)
Vermittlerstrategien und Arbeitsmarkterfolg: Evidenz aus kombinierten Prozess- und Befragungsdaten
Bernhard Boockmann / Christopher Osiander / Michael Stops

Nr. 103 (April 2014)
Evidenzbasierte Wirtschaftspolitik in Deutschland: Defizite und Potentiale
Bernhard Boockmann / Claudia M. Buch / Monika Schnitzer

Nr. 104 (Mai 2014)
Does Innovation Affect Credit Access? New Empirical Evidence from Italian Small Business Lending
Andrea Bellucci / Ilario Favaretto / Germana Giombini

Nr. 105 (Juni 2014)
Ressourcenökonomische Konzepte zur Verbesserung der branchenbezogenen Datenlage
bei nicht-energetischen Rohstoffen
Raimund Krumm

Nr. 106 (Juni 2014)
Do multinational retailers affect the export competitiveness of host countries?
Angela Cheptea

Nr. 107 (August 2014)
Sickness Absence and Work Councils – Evidence from German Individual and
Linked Employer-Employee Data
Daniel Arnold / Tobias Brändle / Laszlo Goerke

Nr. 108 (Oktober 2014)
Exploiting the Potential for Services Offshoring: Evidence from German Firms
Peter Eppinger

Nr. 109 (Oktober 2014)
Capital Income Shares and Income Inequality in 16 EU Member Countries
Eva Schlenker / Kai D. Schmid

Nr. 110 (Oktober 2014)
Offshoring and Outsourcing Potentials of Jobs – Evidence from German Micro-Level Data
Tobias Brändle / Andreas Koch

Nr. 111 (Oktober 2014)
Offshoring Potential and Employment Dynamics
Bernhard Boockmann

Nr. 112 (Oktober 2014)
Is Offshoring Linked to Offshoring Potentials? Evidence from
German Linked-Employer-Employee Data
Tobias Brändle

Nr. 113 (November 2014)
University Knowledge and Firm Innovation – Evidence from European Countries
Andrea Bellucci / Luca Pennacchio