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# University knowledge and firm innovation: evidence from European countries

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**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' innovation activities. An integrated approach that simultaneously considers country- 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 contributes to cross-national disparities in university-industry interactions and 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.

**Keywords** Innovation · University-industry links · Knowledge transfer · University entrepreneurial orientation · Multilevel data

**JEL Classification** O32 · O33 · L20

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## 1 Introduction

Recently in modern knowledge-based economies, a considerable amount of interest has been placed on the interaction between the university sector and industry. This focus is due to the fundamental role of scientific knowledge in spurring firms' innovation, especially in science and technology-based sectors (Klevorick et al. 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/actors are the driving force of innovation. In some of these models, 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 (Bergmam 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 of demand on the firm side, and/or a lack of appropriate incentive structures and supportive institutional factors on the science side. In support of the latter argument, Cunningham and Link (2014), analyzing European Union countries, find that limited access to business-sector facilities and a lack of university funding, disincentivizes universities from cooperating with industry.

A growing literature tries to empirically test the relationship between the university sector and industry, investigating factors that explain why firms draw from universities for their innovation activities. In particular, Laursen and Salter (2004) use a sample of 2655 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 innovation activities from the firm perspective. In addition to firm-specific variables, the analysis examines cross-national differences in the characteristics of 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 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 considered 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 firm-level characteristics on the transfer of knowledge from universities to industry. While other theoretical papers have highlighted the influence of legal, economic and policy environments on the rate of technological change (Bercovitz and Feldmann 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 the sizable variation 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 by 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 has been 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, 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 innovation 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 therefore 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 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 innovation activities. Finally, 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.

The remainder of the paper is organized as follows. Starting from the theoretical and empirical background about university-industry linkages, Sect. 2 develops the research hypotheses. Section 3 describes the data and the econometric model used to test the hypotheses. Section 4 presents the results and Sect. 5, the main conclusions and some policy recommendations.

## 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, for 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-Renko 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. 2003a, b; 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 by 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 and, to create a favorable environment for university-industry interaction in particular.

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 environment determine the role and the type of university knowledge production, as well as 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". The author 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 the 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 a 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 industrially relevant fields of science and an active role in knowledge transfer processes, university systems with a more entrepreneurial orientation should enhance the importance of knowledge transfer to industry.

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

The remaining hypotheses refer to the demand for university knowledge and are derived in accordance with the previous research on the topic. A well-established strand of literature indicates that universities are part of a 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 (Chesbrough 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 Ahuja 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 being radical or incremental. Radical innovations are breakthrough, involve 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 refine or improve on 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 of radical innovation.

Previous research has shown that linking with external organizations gives firms access to information that differs from, but can complement, their 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 attribute more value to academic knowledge, due to the original nature of research performed at universities, 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 and Levinthal (1990) redefines the meaning of internal R&D as the ability to recognize and make use of external knowledge for commercial purposes. The notion of absorptive capacity stresses the importance of a stock of prior knowledge to effectively absorb spillovers while cooperating, and points out that in-house technological capabilities are required to optimally benefit from R&D cooperation. Only with the necessary capabilities to identify, assimilate, and develop useful external knowledge, firms can effectively benefit from incoming technology flows arising from collaborative research. Accordingly, 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 it is of particular importance for firm interactions with universities and other research institutions. Indeed, R&D cooperation with universities is characterized by high level of 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 universities. Many studies have shown that firm size is positively correlated with the propensity of firms to draw from 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 these links 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). Therefore, firm size may be related to the presence of the necessary resources to efficiently implement cooperation with scientific institutions, as a part of the overall 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.

## 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

**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 |

The table reports summary statistics for the variable *Knowledge*, which measures the degree of importance of universities as a source of knowledge for the innovation activities of firms

the Community Innovation Survey (CIS 2008). The CIS is a survey of innovation activities in enterprises from a range of European countries. The survey is carried out by Eurostat, in close cooperation with national institutes of statistics, and since 2004 is conducted every 2 years. 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 by all surveyed countries. 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 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 to only 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 ongoing and/or abandoned innovation activities. Firms which failed to complete the questions on innovation performance activities are also not eligible for the present analysis. The sample includes manufacturing and services 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]

[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.

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.

### 3.2 Dependent variable

As outlined previously, our focus is on the value of transferred knowledge from universities to industry; consequently; we build a variable, *Knowledge*, which measures the degree of importance of universities as a source of knowledge for the innovation activities of firms. Summary statistics for the variable are reported in Table 1.

According to the dependent variable proposed by Laursen and Salter (2004), *Knowledge* proxies for the value that firms attribute to the flow of knowledge generated in the interaction with universities. The variable has been built from the following survey question: "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 a firm does not obtain information from universities; 1 if the level of information that a firm obtained is "low"; 2 if the level of information obtained by a 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 typically 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 firm innovation through multiple channels and focusing only on one or a 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 suggest that there is no spatial correlation among countries in explaining the importance of universities as a source of knowledge for firms' innovation activities. However, results depict great heterogeneity among countries. On average, firms from Germany and Hungary attribute a greater importance to universities. Quite surprising, in a large economy like Italy, firms attribute very low importance to universities: only 3.7 % of firms consider universities as a highly important source of knowledge, while more than 71 % do not use university knowledge at all. On the other hand, the statistics show that university knowledge is highly valued by firms in some small and/or emerging economies like Slovenia and the Czech Republic.

### 3.3 Independent variables

In order to test *Hypotheses H1a* and *H1b*, 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 a Resource-Based perspective 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 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 the scientific base as a whole. The variable *Patents* has been built as the ratio between the number of patent applications of 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 our sample, 7 % 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 a high degree of entrepreneurial activities by universities (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 expenditure funded by the business enterprise sector.[2] Summary statistics reported in Table 2 show that, on average, only 2 % 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 5-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.

All other hypotheses are tested by means of regressors at the firm level. As shown in Sect. 2, the importance of universities as a source of knowledge for firms' innovation activities depends not only on the institutional and macroeconomic context, but also on several micro-factors. Therefore, to avoid country-level covariates simply capturing 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 *Hypothesis 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 CIS 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 the remaining external sources of knowledge are coded as a binary indicator with the value

[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.

**Table 2** Descriptive statistics and correlations

| | Mean | SD | Min | Max | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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) Export | 0.57 | 0.50 | 0 | 1 | 0.14 | 0.13 | 0.15 | 0.03 | −0.00 | 1.00 | | | | | | | |
| (7) High tech | 0.24 | 0.43 | 0 | 1 | 0.08 | 0.06 | 0.11 | 0.00 | −0.00 | 0.25 | 1.00 | | | | | | |
| (8) Knowledge intensive | 0.21 | 0.40 | 0 | 1 | 0.04 | 0.10 | 0.05 | 0.00 | −0.00 | −0.13 | −0.28 | 1.00 | | | | | |
| Country-specific variables | | | | | | | | | | | | | | | | | |
| (9) Citations | 4.77 | 2.41 | 0 | 7.61 | 0.02 | −0.10 | 0.05 | 0.00 | −0.00 | 0.01 | 0.02 | 0.01 | 1.00 | | | | |
| (10) GERD business-university | 0.02 | 0.02 | 0.00 | 0.06 | −0.01 | −0.04 | −0.08 | −0.21 | −0.00 | 0.08 | 0.08 | 0.04 | 0.28 | 1.00 | | | |
| (11) Patents | 0.07 | 0.07 | 0.02 | 0.28 | 0.02 | 0.10 | −0.03 | 0.05 | 0.00 | 0.09 | −0.04 | 0.03 | −0.46 | −0.22 | 1.00 | | |
| (12) Protection | 6.00 | 1.04 | 3.8 | 8.3 | 0.03 | 0.02 | −0.03 | −0.07 | 0.00 | 0.13 | 0.04 | 0.05 | 0.45 | 0.47 | 0.24 | 1.00 | |
| (13) Education | 0.04 | 0.00 | 0.03 | 0.07 | 0.11 | 0.16 | 0.07 | 0.22 | 0.01 | 0.05 | −0.02 | 0.01 | −0.07 | −0.31 | 0.35 | 0.13 | 1.00 |

The table presents summary statistics and pairwise correlation coefficients for the variables used in the empirical analysis of 0 for the answer ‘not used’ and the value of 1 for all other answers. These indicators are summed to make the *Openness* variable which, consequently, ranges between 0, for firms that do not use any 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 4–5 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 CIS 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’ actual cooperation strategies.

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, each equal to 1 for firms introducing product (goods and/or 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 to the firms themselves. Both variables are considered as proxies for radical innovations and are used to *test hypothesis H3*. In our sample, the percentage of radical innovators is higher than incremental innovators (34 and 12 %, respectively).

The model further includes various firm structural factors to test Hypotheses H4 and H5. 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*). Such a measure is the most commonly used proxy in the empirical literature and accounts for the effort of firms to build a solid stock of knowledge (Belderbos et al. 2004; Nieto and Santamaría 2007). Cohen and Levinthal (1990) have discussed that absorptive capacity is largely a function of the firm’s existing level of knowledge. Through R&D investments, a firm generates new knowledge that, in turn, improves the ability to assimilate and exploit externally available information. This implies that absorptive capacity may be created as a byproduct of a firm’s R&D investments. This reasoning is supported also by Escribano et al. (2009), which consider firms with greater R&D capacity as having a well-established technology base that allows them to efficiently assimilate external knowledge flows. Furthermore, Kodama (1995) asserts that internal R&D is crucial in supporting different research projects and, consequently, ‘learning by doing’. This learning, in turn, enables firms to import and use externally created knowledge. 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 % 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*).

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 firms from high- and medium-technology industries and knowledge-intensive services, respectively. To control for firms ability to compete on the foreign market the dummy variable *Export* is built. The variable equals 1 for firms exporting their goods and services and 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). In order to check the robustness of supply-side factors for the potential confounding effect of other institutional aspects, we also introduce in the model the variable *Education* that measures the government expenditures on education as a share of GDP (the source of the data is Eurostat). The last control measures the protection of intellectual and property rights at the 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. It is computed at country level, as the average of firms' perceptions of the effectiveness of their national legal system in protecting intellectual and property rights (Table 2).

### 3.4 Econometric model

Since the dependent variable is a multinomial-choice variable with a logical order (the values of *Knowledge* range between 0 and 3), an ordered logit model (OLM) is estimated. The models for ordinal outcomes can be described in terms of a latent variable. The structural model is:

$$y_i^* = X_i\beta + \varepsilon_i$$

where $y_i^*$ is the latent variable, $i$ indexes observations, $X_i$ is a set of covariates, and $\varepsilon_i$ is the error term. The latent variable can be divided into $J$ ordinal categories, so that the observed variable is:

$$y_i = m \quad \text{if } \tau_{m-1} \le y_i^* \le \tau_m, \quad \text{for } m = 1 \text{ to } J$$

where the thresholds $\tau_1 - \tau_m$ are estimated from the sample. The probabilities of observing $y = m$ are given by

$$Pr(y = m|X) = F(\tau_m - X\beta) - F(\tau_{m-1} - X\beta)$$

In our analysis we rely on the OLM, which assumes a logistic cumulative distribution function F(.) of the random error. *Knowledge*, the dependent variable, has four categories depending on the importance of university as a source of information for the firms included in the CIS 2008. Thus, 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 the respective regression coefficient in the ordered log-odds scale, holding other regressors constant. Using column 2 as an example, a unit increase in the openness variable increases the log-odds to be in the category of high importance by 0.66. 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] 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 | | 0.66*** | 0.66*** |
| | | (0.04) | (0.05) |
| Cooperation | | 0.18*** | 0.20*** |
| | | (0.02) | (0.02) |
| Product mkt | | 0.06** | 0.07** |
| | | (0.03) | (0.03) |
| Process mkt | | 0.02 | 0.09 |
| | | (0.05) | (0.05) |
| Absorptive capacity | | 0.03*** | 0.03*** |
| | | (0.01) | (0.01) |
| Size | | 0.23*** | 0.18*** |
| | | (0.05) | (0.06) |
| Size squared | | −0.01*** | −0.01*** |
| | | (0.00) | (0.00) |
| Export | | 0.17*** | 0.16*** |
| | | (0.05) | (0.04) |
| High tech | | 0.34*** | 0.28*** |
| | | (0.12) | (0.11) |
| Knowledge intensive | | 0.47*** | 0.44*** |
| | | (0.05) | (0.04) |
| Citations | 0.10*** | | 0.06*** |
| | (0.00) | | (0.02) |
| GERD business-university | 27.82*** | | 24.85*** |
| | (1.66) | | (5.40) |
| Education | 36.20*** | | 3.18 |
| | (2.91) | | (12.66) |
| Patents | 2.79*** | | 1.65* |
| | (0.36) | | (0.97) |
| Protection | −0.37 | | −0.30 |
| | (0.36) | | (0.22) |
| Observations | 45,277 | 45,277 | 45,277 |
| Pseudo R2 | 0.08 | 0.21 | 0.22 |
| Log likelihood | −45,884 | −36.158 | −35,862 |

The table reports the estimates of our OLM in which the dependent variable is *Knowledge*. Column (1) shows the OLM estimates in which only variables referring to environmental and institutional context are considered. Column (2) shows the OLM estimates only with micro-factors on the importance attributed to university knowledge. Column (3) shows the OLM estimates of the integrated approach that simultaneously considers both demand-side factors for knowledge, captured at firm-level, and supply-side factors, captured at country-level. ***, **, * Indicate that coefficients are statistically significant at the 1, 5 and 10 % level, respectively. Coefficients are in log-odds ratio form. Ancillary parameters are not reported. Standard errors clustered at country level are shown in parentheses

## 4 Findings

The empirical analysis mainly 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' innovation 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 individual factors, the research hypotheses developed in Sect. 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 links with university, column (2) includes 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.

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 innovation activities by 27.82 and 2.79, respectively. The quality of academic research (*Citations*) is also associated with highly 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 characteristics of the overall research university system seem 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 their internal strategies for knowledge exploitation and exploration. Hence, 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 innovation activities. These findings provide support to *Hypothesis H2* and are in line with Katila and Ahuja (2002) and Laursen and Salter (2004). The authors found that the research strategies of firms play 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 H3* 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 product innovators are more likely to benefit from information generated from universities than other companies. 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. However, the coefficient of *Process mkt* is not statistically different from 0, suggesting that university knowledge is not so highly valued for firms implementing radical process innovations.

The estimates also confirm the importance of structural factors in explaining why some firms draw more from universities. In line with existing studies, the variable *Absorptive capacity* has 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. This finding supports *Hypothesis H4* 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.

Lastly, the empirical evidence on the effect of firm size is mixed. The average effect of the coefficient capturing firm 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. Such findings are consistent with *Hypothesis H5*. A possible explanation is that large firms are, in general, more likely to draw form universities; however, for firm size above a certain threshold, the value of knowledge acquired from external sources is only a complement of knowledge generated with internal resources.

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

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 innovation activities. Such results are consistent with the previous literature. The coefficient attached to *Education* has the expected positive sign but weak statistical significance. 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-competitive partners since they do not compete in the market but enhance their own respective skills (Huang and Yu 2011). Furthermore, the more generic nature of research projects with universities should involve less appropriation issues compared to the more commercially sensitive cooperation with customers/suppliers or competitors.

For the purpose of interpretation, Table 4 shows the marginal changes in the predicted probability for each category of the dependent variable and with reference to the more comprehensive model specification reported in column (3) of Table 3. For the binary regressors, the marginal change is the change in the predicted probability given a change in the regressors from 0 to 1. For example, firms belonging to high tech industries are 0.5 % more likely than other firms to consider universities as an important source of knowledge.

**Table 4** Marginal changes in the predicted probabilities of the OLM

| | Not used | Low | Medium | High | Average change |
|---|---|---|---|---|---|
| Openness | −0.3160 | 0.1882 | 0.0956 | 0.03222 | 0.1580 |
| Cooperation | −0.0518 | 0.0325 | 0.0146 | 0.0046 | 0.0259 |
| Product mkt | −0.0124 | 0.0078 | 0.0035 | 0.0011 | 0.0062 |
| Process mkt | −0.0173 | 0.0107 | 0.0049 | 0.0015 | 0.0086 |
| Absorptive capacity | −0.0203 | 0.0127 | 0.0057 | 0.0018 | 0.0101 |
| Size | −0.0178 | 0.0111 | 0.0050 | 0.0016 | 0.0089 |
| Size squared | 0.0117 | −0.0073 | −0.0033 | −0.0010 | 0.0058 |
| Export | −0.0289 | 0.0182 | 0.0081 | 0.0026 | 0.0144 |
| High tech | −0.0557 | 0.0343 | 0.0161 | 0.0052 | 0.0278 |
| Knowledge intensive | −0.0801 | 0.0488 | 0.0236 | 0.0077 | 0.0400 |
| Citations | −0.3026 | 0.0189 | 0.0085 | 0.0027 | 0.0151 |
| GERD business-university | −0.0699 | 0.0438 | 0.0198 | 0.0063 | 0.0349 |
| Education | −0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Patents | −0.0197 | 0.0123 | 0.0055 | 0.0017 | 0.0098 |
| Protection | 0.0504 | −0.0316 | −0.014 | −0.0045 | 0.0252 |
| *Pr*(*y*\|*x*) | 0.7447 | 0.1785 | 0.0592 | 0.0174 | |

The table shows the marginal change in the predicted probabilities for each category of the dependent variable and with reference to the full model specification listed in Table 3—column 3

Regarding the other variables, the marginal change refers to the change in the predicted probability given an increase of the regressor by one standard deviation. For example, a one standard deviation increase in the *Openness* variable increases the predicted probability of the 'high' outcome by 3.2 %. The last row of the table reports the predicted probabilities at the mean values of all regressors.

## 4.1 Robustness

In this section, the robustness of the ordered logit estimates is tested. The first 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. In the second test, a multilevel approach is used to explicitly take into account the variation of the dependent variable across the countries included in the sample.

### *4.1.1 Generalized ordered logit model*

The OLM 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 the Brant test 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*, *Size squared*, *High tech*, and *Citations*.

Therefore, as a robustness check for the OLM, we provide additional estimates with a generalized ordered logit model (GOLM) which allows for different estimates of coefficients across the 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 still more parsimonious and interpretable than non-ordinal methods.

GOLM has been regressed on our full specification tabulated in Table 3—column (3). Table 5 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 that place the highest value on university knowledge.

All of the results obtained by OLM seem to be confirmed. GOLM estimates confirm the role of universities in determining the value of scientific knowledge for industry and in explaining cross-national disparities. Firms located in countries where the university system is characterized by both higher entrepreneurial orientation and high quality of academic research, place more value on university knowledge. This again provides empirical support to theoretical frameworks that emphasize the relevance of environmental and institutional conditions in fostering university-industry linkages. Findings also hold in regard to demand-side factors. In particular, estimates 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 hypothesis concerning the inverted U-shaped relationship between firm size and value of academic knowledge.

**Table 5** Generalized ordered logit estimates explaining the importance of universities as a source of knowledge

| | (1) | (2) | (3) |
|---|---|---|---|
| Openness | 0.72*** | 0.51*** | 0.37*** |
| | (0.05) | (0.04) | (0.04) |
| Cooperation | 0.18*** | 0.23*** | 0.25*** |
| | (0.02) | (0.02) | (0.02) |
| Product mkt | 0.07** | 0.07** | 0.07** |
| | (0.03) | (0.03) | (0.03) |
| Process mkt | 0.09 | 0.09 | 0.09 |
| | (0.06) | (0.06) | 0.06) |
| Absorptive capacity | 0.02*** | 0.03*** | 0.03*** |
| | (0.01) | (0.00) | (0.01) |
| Size | 0.83*** | 0.18*** | 0.04 |
| | (0.18) | (0.05) | (0.05) |
| Size squared | −0.07*** | −0.04** | −0.02 |
| | (0.01) | (0.00) | (0.00) |
| Export | 0.15*** | 0.15*** | 0.15*** |
| | (0.03) | (0.03) | (0.03) |
| High tech | 0.35*** | 0.24** | 0.07 |
| | (0.12) | (0.11) | (0.08) |
| Knowledge intensive | 0.44*** | 0.44*** | 0.44*** |
| | (0.04) | (0.04) | (0.04) |
| Citations | 0.06*** | 0.05** | 0.07** |
| | (0.02) | (0.02) | (0.03) |
| GERD business-university | 25.80*** | 25.80*** | 25.80*** |
| | (5.30) | (5.30) | (5.30) |
| Education | 2.46 | 2.46 | 2.46 |
| | (12.34) | (12.34) | (12.34) |
| Patents | 1.71* | 1.71* | 1.71* |
| | (0.99) | (0.99) | (0.99) |
| Protection | −0.31 | −0.31 | −0.31 |
| | (0.26) | (0.26) | (0.26) |
| Observations | 45,277 | | |
| Pseudo R2 | 0.24 | | |
| Log likelihood | −35,015 | | |

The table reports the estimates of our GOLM for each of the binary models based on the full specification listed in Table 3—column 3. Column (1) contrasts firms with dependent variable equal to 0 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. ***, **, * Indicate that coefficients are statistically significant at the 1, 5 and 10 % level, respectively. Coefficients are in log-odds ratio form. Ancillary parameters are not reported. Standard errors clustered at country level are shown in parentheses

Indeed, the coefficient of *Size* and *Size squared* are statistically significant in column (1) and (2), but not in column (3), and point estimates decrease with the increasing importance of university knowledge. This means that the positive relationship between firm size and university knowledge has a decreasing marginal rate and disappears when the firms that place the highest value on university knowledge are contrasted with other firms (Table 5).

### *4.1.2 Multilevel ordered logit model*

Hierarchical or multilevel modeling is becoming an increasingly used instrument of analysis in the field of social sciences. Recently, for example, Van Oort et al. (2012) highlight the potential of this econometric approach in agglomeration and economic growth studies, while Srholec (2014) apply a multilevel model to investigate cross-country differences in innovation cooperation.

The multilevel approach involves relationships between variables which are measured at different hierarchical levels and allows the micro and macro level to be modeled simultaneously. In comparison to standard approaches, multilevel models have two major advantages. Firstly, by separating the linkages between the micro and macro level, such models are able to assign variability to the appropriate context. In the present paper, this means that we can assess the extent to which variance in the importance of university knowledge can be attributed to between-firm variance or to between-country variance. Secondly, multilevel models account for unobserved heterogeneity by including a random intercept and allow verification of whether relationships vary across contexts through the inclusion of random coefficients.

Given the nature of our dependent variable, and in order to account for the unobserved heterogeneity at country level, we estimate a random intercept multilevel ordered logit model (MOLM). Once again MOLM is regressed on the full specification as in Table 3—column (3). The estimates, reported in Table 6, confirm all results obtained by OLM and GOLM. The likelihood-ratio shown at the bottom of the table indicates that there is enough

**Table 6** Multilevel ordered logit estimates explaining the importance of universities as a source of knowledge

| | |
|---|---|
| Openness | 0.66*** (0.01) |
| Cooperation | 0.20*** (0.01) |
| Product mkt | 0.07*** (0.02) |
| Process mkt | 0.10*** (0.03) |
| Absorptive capacity | 0.03*** (0.01) |
| Size | 0.18*** (0.03) |
| Size squared | −0.01*** (0.00) |
| Export | 0.16*** (0.02) |
| High tech | 0.28*** (0.02) |
| Knowledge intensive | 0.42*** (0.02) |
| Citations | 0.08*** (0.01) |
| GERD business-university | 28.25*** (2.70) |
| Education | 7.07** (3.53) |
| Patents | 2.50*** (0.62) |
| Protection | −0.38 (0.26) |
| Observations | 45,277 |
| Wald $\chi^2$ | 12,510 |
| Log likelihood | −35,835 |
| LR test versus ologit model (*p* value) | 0.00 |

The table reports the estimates of our multilevel ordered logit model (MOLM) in which the dependent variable is *Knowledge*. MOLM is regressed on the full specification as in Table 3—column (3). ***, **, * Indicate that coefficients are statistically significant at the 1, 5 and 10 % level, respectively. Coefficients are in log-odds ratio form. Ancillary parameters are not reported. Standard errors clustered at country level are shown in parentheses variability between countries to adopt a multilevel ordered logistic model as an alternative econometric strategy to the standard ordered logistic model.

## 5 Conclusions

Knowledge generating institutions are considered 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' innovation 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 strategies 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 particularly 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 an important sources of knowledge. On the other hand, the relationship between firm size and the importance of university knowledge appears more complex than typically shown in the previous literature. Overall, with the increase of firm size, the value of academic knowledge increases too but at a decreasing marginal rate. 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 the characteristics of national innovation systems also 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' innovation activities is positively affected by the entrepreneurial orientation of universities and by the quality of university research.

Such results help to explain cross-country disparities in university-industry interactions among European countries and indicate that innovation systems based on the entrepreneurial role of universities are of great importance for the generation and the 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. (2013) 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 an interesting extension, the empirical analysis should be extended to include additional countries like US or Japan, that is, countries with which Europe lags behind in regard to university-industry interactions.

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