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International patenting decisions: empirical evidence with Spanish firms

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Abstract This paper analyses the determinants of firms' decisions to patent abroad. We use data spanning 2005–2013 of Spanish firms from PITEC, a panel database carried out by the INE (The National Statistics Institute). We focus on patenting firms and consider that firms' decisions to apply for patents in foreign patent offices may be driven by two kinds of motivations: first, to exploit the patent in international markets where there is potential demand for the invention and, second, to protect the invention abroad when the quality of the invention is high enough. In the first case we refer to market-driven determinants and, in the second case, to innovation type-driven determinants. We empirically analyse these factors using information on firms' sales in different geographic international markets, and also indicators of the quality and scope of the innovations. We distinguish among EPO, USPTO and PTC patents, and estimate, first, a multivariate probit model to determine the factors underlying the decision to apply for patents in these foreign offices. Second, we estimate a multivariate model to explain the shares of patent applications in each one of the offices.

Keywords International patenting · Market-driven determinants · Innovation type-driven determinants · Firm-level data · Multivariate models

JEL Classification D22 · C30 · O34

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1 Introduction

The widespread phenomenon of globalization is inducing firms towards an increasing internationalization of innovative activities. As firms are forced to operate on a global basis, they need to protect their innovations not only at home but also abroad. Patents are one of the main instruments allowing firms to protect their inventions by temporarily appropriating the returns to their innovative investments. However, patent laws are based on the principle of territoriality, meaning that firms must obtain a patent in every country in which they seek protection.

Analysing international patenting behaviour by firms is relevant since patenting abroad is an important aspect of the extent of internationalization of technology of a country, and it is also one of the main mechanisms of technological diffusion across countries, contributing to economic growth and prosperity of nations. However, while there are a huge number of studies dealing with patenting behaviour, the analysis of the drivers to patent abroad at the firm level has been less explored in the literature, and in this paper we want to fill this gap.

The aim of the paper is to provide new insights into the understanding of international patent application strategies by firms. We draw our data from the Technological Innovation Panel (PITEC), a panel dataset recording the innovation activities of Spanish firms, carried out by the INE (The National Statistics Institute) since 2003. For our analysis, we use information from PITEC for the period 2005–2013.[1] PITEC provides information on patent applications in the Spanish Patents and Trademarks Office (SPTO), which is the national patent office, and, regarding patent applications abroad, it distinguishes among patent applications via the European Patent Office (EPO), the US Patent and Trademark Office (USPTO), and the Patent Cooperation Treaty (PCT).[2] Instead of focusing on all firms, we focus on the sample of patenting firms, and analyse the factors driving them to apply for patents abroad as against the decision to patent domestically, that is, the factors that affect both the degree and the patterns of internationalisation of patenting.

Figure 1 presents the percentage of firms applying for patents abroad in our sample of patenting firms over the period of analysis, distinguishing among the different patent offices. We observe that Spanish firms apply for patents mainly at the Spanish Patents and Trademarks Office, which represents the higher

[1] We do not use the data for 2003 and 2004 due to enlargement and restructuring of the sample of firms in the survey after 2004.

[2] The Patent Cooperation Treaty is an international agreement, administered by the World Intellectual Property Organization (WIPO), for filing a single application that is valid in more than 150 member countries. Although the PCT system is, properly speaking, a patent filing system rather than a patent office, we shall refer to it as another of the 'patent offices' mentioned throughout the paper. A patent application filed under the PCT is called an international patent application. The purpose of the PCT is making it easier and initially cheaper to file a patent application in a large number of countries. By filing through the PCT process the firm can embark on the path to seek patent protection for an invention simultaneously in every country that is a member to the Treaty (see details in http://www.wipo.int/pct/en/).

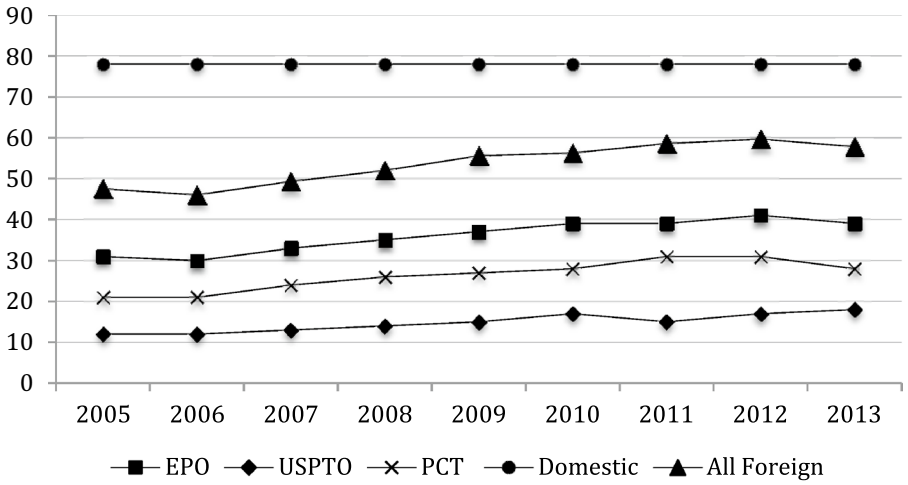

Fig. 1 Percentage of firms applying for patents by Patent Office. This Figure corresponds to the sample of patenting firms. The percentages sum up more than 100 since there are firms filing for patents simultaneously in several patent offices

percentage along the period analysed, although we also notice a mild decreasing trend in this percentage (from 78% in 2005 to 71% in 2013, approximately). Regarding international patent applications, we observe instead a mild increasing trend during the period under analysis for the three types of patents, EPO, USPTO and PCT.[3] Geographical proximity seems to be an important determinant of patenting abroad: the higher "proximity" of European countries could explain why Spanish firms file patent applications to the EPO to a higher extent than to the USPTO or PCT. This increasing trend in patenting abroad, which is in line with international patenting trends in other countries (see, e.g., Yang and Kuo 2008), could suggest an increasing value of these international patents for Spanish firms, and/or a higher internationalization of Spanish firms in their product market.

In order to disentangle firms' determinants of international patenting decisions, we consider two types of motivations that allow us to distinguish between market-driven determinants and innovation type-driven determinants. In the first case, inventors seek for patents in order to exploit them in international markets where there is potential demand for the invention. In the second case, firms seek to protect inventions abroad when the quality of the invention is high enough.

As regards the first type of motivation, that is, the geographic area where firms want to seek protection, there are different routes depending on the desired country coverage. First, if they want to seek protection at the European level, that is,

[3] Notice that the percentages in Fig. 1sum up more than 100 since there are firms filing for patents simultaneously in several patent offices.

in several European countries, they may want to file applications to the EPO.[4] When firms want to seek protection of inventions in the US market, they may file patent applications in the USPTO. Finally, when firms want to seek protection in a broader coverage of countries, they may apply for a PCT patent. The main advantage of the PCT route is that firms have more time to finally decide in which particular countries they may want to seek patent protection, and the possibility to postpone the costs for numerous national patent applications.

Regarding the second type of motivation, that is, the innovation-type determinants, we consider that inventions that are broader in scope may have higher market values and, hence, they may be more prone to be patented abroad. Additionally, higher quality innovations are probably worthier of being patented abroad. This is because patenting abroad is generally costlier than patenting only at home. The costs include not only the fees to be paid in each case (generally higher in the case of international patents) but also informational and bureaucratic costs that tend to increase with the geographical distance.[5] Hence, firms will choose to patent abroad when the expected incremental revenues from these patents exceed the additional costs to be incurred.[6]

There are a number of other studies related to our work. First, using a multi-country approach and statistical data from patent offices, a number of studies have documented the positive links between international patenting and trade-related factors (Dosi et al. 1990; Eaton and Kortum 1996; Guellec and van Pottelsberghe de la Potterie 2001; Yang and Kuo 2008).[7] At the firm level, empirical studies analysing

[4] Up to thirty-five countries can be designated on an EPO patent application. However, we do not have information on the number of individual European countries applied for by each firm. The European patent procedure is more expensive than direct application in a single country patent office. As a rule, however, the European patent coverage per country is cheaper than a single national patent application if the firm seeks patent protection in at least three European countries (Licht and Zoz 1998).

[5] According to De Rassenfosse and van Pottelsberghe de la Potterie (2013), who survey patent fees on a number of patent offices worldwide, patent fees play an important role in determining the demand for patents.

[6] There could be also some room for strategic international patenting pursuing blocking competitors from using technologies, the use of patents for negotiation with rivals for technology access, or as signals of firms' market value to have access to capital markets (see, e.g., Blind et al. 2006). An empirical analysis of the strategic use of patents by firms is Hall and Ziedonis (2001), who showed that patenting rose sharply in the 1990s in the US semiconductor industry in response to the risk of hold up generated by patent "thickets" (fragmentation of patent rights). Noel and Schankerman (2013) analyse the strategic patenting behaviour in the US computer software industry, focusing in particular in the accumulation of patents as a way to increase bargaining power with regards technology rivals, and in patent thickets, showing that these two strategic patenting activities affect innovation and market value of software firms. The analysis of these strategic issues is out of the scope of the paper.

[7] Dosi et al. (1990) estimated trade and patent flows among a number of OECD countries and found that cross-country patenting was positively associated with trade flows. Eaton and Kortum (1996) also empirically observed among OECD countries that exports had a significantly positive impact on the number of patents filed in target countries. Guellec and van Pottelsberghe de la Potterie (2001), using data on 29 OECD countries, found that international patent-related indicators are positively correlated with openness to external trade (imports and exports relative to GDP). Yang and Kuo (2008) provide an empirical investigation on the national outbound of international patenting using cross-patenting from 30 countries in the World Intellectual Property Organization (WIPO) between 1995 and 1998, and found that international patenting is strongly and positively associated with trade related factors, such as exports and FDI.

firms international patenting decisions are scarcer. Licht and Zoz (1998), using a sample of German patenting firms, observed that firms were applying for more patents in those foreign countries where they were exporting more. Regarding differences in the innovation type as determinants of international patent applications, Jaffe and Lerner (2004) have suggested that inventions differ in their quality and not all of them are worth patenting abroad. Maurseth and Svensson (2014) analysed a sample of individual patents owned by small Swedish firms and inventors and found that the propensity to patent in a foreign country depends on the quality of the patented invention and on country characteristics. Also Chan (2010) has documented that differences in innovation types determine international patent application decisions in agricultural biotechnology.

Our study contributes to the existing literature in at least three aspects. First, although the analysis of firms' decisions to patent their innovations has been profusely studied in the literature (see, e.g., Hall and Harhoff 2012, and references therein), few studies have addressed empirically at the firm level, the determinants of patenting abroad as compared to patenting domestically, distinguishing among different foreign patent offices. We analyse these issues on a sample of Spanish patenting firms. Second, our data enables us to construct a considerable amount of variables capturing several dimensions of the firms' innovation R&D activities as well as other firms' characteristics typically unavailable in most studies using statistical data from patent offices. In particular, we empirically capture market demand-driven factors using information on firms' volume and geographic destiny of exports, and innovation type-driven factors by including proxies for the quality and scope of innovations. Although a number of papers have documented the relationship between international patents and trade related factors using data from patent offices and at the country level, innovation related factors at the firm level have been less explored in the literature and this is one of our main contributions. Finally, we distinguish between the qualitative decision on whether to apply for a patent abroad and in which patent office, as against the decision to patent at the home office, and the corresponding quantitative decision regarding the share of patents applications in each office. For qualitative measures we estimate a probit model, whereas for quantitative measures we estimate by OLS a logit transformation of patent shares. In both cases we estimate, first, single equations for patent applications abroad, regardless of the chosen patent office, and, second, multivariate equations jointly estimated for patenting activity at each office. Since all estimations in the paper have as reference category the patenting activity of firms in the Spanish office, our analysis is focused on the firm's decision to patent internationally. For this reason, econometric results in the paper should be understood as how particular variables affect the likelihood of patenting abroad versus patenting domestically.[8]

[8] An alternative panel data source providing information on patenting at the firm level is the ESEE (Encuesta sobre Estrategias Empresariales, Fundación SEPI). However, this data source does not allow distinguishing among international patent applications to different geographical areas. A recent analysis using this data source for Spanish firms' patents can be found in Beneito et al. (2014).

Our findings provide information on the drivers of the internationalisation of patents by Spanish firms, indicating that both market-driven and innovation-type factors are important determinants of the decision to patent abroad. In particular, the estimated effects of the trade-related factors suggest that firms are more likely to patent in those geographical areas where they export more, and also that international patenting seems to be more oriented towards market enlargement than to accessing new markets. Among the innovation-type factors, our findings suggest that those firms with innovation projects that are more R&D intensive, that are undertaken by more qualified R&D workforce, and that are associated with innovation outcomes of higher quality are also more prone to patent in international offices.

The rest of the paper is organized as follows. Section 2 introduces the empirical model, presenting the data, variables and a descriptive analysis. Section 3 reports the econometric results and, finally, Sect. 4 concludes.

2 Empirical model: data, variables and descriptive analysis

Our empirical analysis is based on data from the Technological Innovation Panel (PITEC). PITEC is a firm-level panel data set carried out annually by the National Statistics Institute in Spain (INE) that collects information related to innovation activities of firms with more than ten employees in manufacturing and services.[9] PITEC follows the structure of the European Community Innovation Surveys (CIS) and, hence, it provides widely accepted innovation indicators and variables. However, differently to CIS data, PITEC is designed as a panel data survey. Answering the survey is mandatory for firms. In this paper, we use information from PITEC for the period 2005–2013, and focus not on all firms but, instead, on the sample of patenting firms.

To address empirically the main factors underlying firms' decisions to patent abroad, as against the decision to patent domestically, we specify an estimation model (econometric details to be given in the next section) where the dependent variable reflects international patent applications (with several variants, as we describe below), and the set of explanatory variables account for two groups of variables meant to capture, first, market-driven determinants of international patent applications and, second, innovation-type determinants. An additional set of variables is also added to control for effects likely related to our main variables of interest. We can write the main estimation equation in a compact form as follows:

$$N_{it3} = \alpha + \beta\, m_{it3} + \gamma\, q_{it3} + \delta\, c_{it3} + \lambda_t + \lambda_j + \nu_{it3} \tag{1}$$

where subscript i refers to the firm and subscript $t3$ is used to express that the information corresponds to a the 3-year period, due to the particular timing of many of the variables we use from PITEC. In particular, several questions made to firms in the questionnaire corresponding to a given year t are of the type "please, indicate the number of patents applied for by the firm during years t, $t-1$ and $t-2$." However,

[9] A description of the survey can be found at the following link (in Spanish): https://icono.fecyt.es/pitec.

some other variables in PITEC are annual or 'current' variables, that is, the firm is required to answer about some indicator/variable referred to the current year *t*. In order to maintain homogeneity in the timing of the variables used in our analysis, for those variables that are originally annual we construct averages over 3-year periods.[10] Using this approach and cleansing the data from missing values in relevant variables for our analysis, we end up using an unbalanced panel of 5400 observations corresponding to 1869 firms.

First, in Eq. (1), the dependent variable N_{it3} stands for our indicator of international patenting propensity. In the econometric estimation we investigate with different definitions of this dependent variable. More specifically, we use a dichotomous variable indicating whether or not a firm files for a patent in any patent office abroad, and also a variable defined as the share, or proportion, of total patent applications filed in foreign patent offices. We further distinguish, both for the dichotomous variable and for the share of patent applications abroad, which is the international office where the firm has applied for patents. Our analysis is restricted by data availability in PITEC. In particular, PITEC provides information on whether the firm has applied for patents and the number of patents applications, distinguishing among the SPTO, the EPO, the USPTO and PCT patents.[11]

Among the right hand side elements in Eq. (1), m_{it3} represents a vector of variables accounting for the market destiny of the firm's sales. We exploit a set of variables for which PITEC provides information in this regard. First, the volume of exports as percentage over total firm's sales (or export share, *Exports*), which proxies for the degree of openness of the firm and, thus, measures how important for the firm are foreign markets. Once accounted for the export share, two dummy variables are constructed that indicate whether the main export market for the firm is the European Union (*Exp_EU)* or rather some country in the rest of the world (*Exp_RoW*). Finally, in this group of variables related to the market orientation of the firms, we include two discrete variables constructed from two questions directly addressed to firms in which they rank how important on a scale from 1 to 4 is for the firm as a goal of its innovation efforts to penetrate new markets (*New_markets*) or, either, to gain market share in the firms' current main market (*Gain_share*).

Continuing with the elements in Eq. (1), q_{it3} stands for a vector of variables gathering the type of innovations achieved by firms, which ultimately determine their patent applications. Firstly, we distinguish between product and process innovations (*Product innov.* and *Process innov.*) with a dummy variable constructed accordingly in each case. Given their different nature, we expect these two variables to have a differentiated impact on the propensity to patent abroad and, in particular, as suggested by the literature, firms tend more often to protect product innovations through patents (Levin et al. 1987). Secondly, and what is

[10] In the Appendix we provide a detailed definition of all the variables used in our analysis. We also specify which variables correspond originally to a 3-years period and which variables are originally annual and we calculate its average over a 3-years period.

[11] PITEC does not provide information on patent applications to other individual countries patent offices. However, EPO, USPTO and PCT represent the bulk of foreign patent applications by Spanish firms.

Table 1 Distribution of patent applications by Patent Office

	Percentages	Average number of patents per firm-year (SE)
Patents in Spanish Office	57.56	1.032 (5.755)
Patents abroad	42.44	1.087 (3.824)
EPO patents	20.95	0.520 (2.067)
USPTO Patents	5.82	0.208 (1.072)
PCT Patents	15.67	0.359 (1.651)
All patent applications	100%	2.119 (7.487)

Table 2 Correlation coefficients among Patent Office firms' choices

	Spanish Office	Abroad	EPO	USPTO	PCT
Spanish Office	1				
Abroad	− 0.5287***	1			
EPO	− 0.2540***	0.6952***	1		
USPTO	− 0.0801***	0.3887***	0.3448***	1	
PCT	− 0.2730***	0.5609***	0.1136***	0.2617***	1

***$p < 0.01$

more interesting for the sake of our paper, we construct a set of indicators that proxy for the scope and innovative content of the innovations obtained by the firm. On the one hand, two variables are constructed that measure directly the outcome of firms' innovation. The first of these measures (*Sales_innov_firm*) accounts for the percentage of firms' sales from products that are new for the firm but not for the market, whereas the second (*Sales_innov_market*) is defined as the percentage of firms' sales coming from products that are not only new for the firm but also new in the market. Naturally, as it has been extensively acknowledged by the innovation-patents literature since Griliches (1990), not all the inventions related to patents are eventually translated into marketable products, and, on the other hand, successful marketable products are often not protected by patents. Thus, the link between patents and innovative sales is not clearly defined in all the cases. However, we find it sensible to assume that patents in other countries are necessarily related to innovations new to the market and not only to the firm and, thus, the second of the variables above (*Sales_innov_market*) is expected to show greater association with innovations of higher scope and, hence, with international patents.[12] On the other hand, and from the point of view of the inputs of

[12] Empirical works using data from the Community Innovation Surveys (CIS) have extensively used firms' innovative sales as one of the preferred measures of innovation outcomes. Innovative sales from products new to the market are considered as indicative of innovation outcomes of higher scope than those corresponding to products new to the firm. Bloch and Graversen (2008) investigate the characteristics of this measure and how well it works in empirical analysis. The authors conclude that, although with its own shortcomings, a measure of innovative sales is a usable proxy of 'economically valuable knowledge'.

Table 3 Correlation coefficients among number of firms' patent applications in different Offices

	Spanish Office	Abroad	EPO	USPTO	PCT
Spanish Office	1				
Abroad	0.1887***	1			
EPO	0.2321***	0.8674***	1		
USPTO	0.0925***	0.6812***	0.4461***	1	
PCT	0.0865***	0.7884***	0.4678***	0.3705***	1

***$p < 0.01$

the innovation processes of firms, we construct another set of variables that try to capture how '*ambitious*' are the R&D projects carried out by firms, under the assumption that, the more ambitious the project is, the higher the innovative content, that is, the quality and scope of the finally obtained innovation. In particular, we assume that projects that are more R&D intensive (measured as the percentage of total employees of the firm that work in the R&D lab, *R&D_intens*), that count on a higher percentage of PhD holders among the R&D staff (*PhD in R&D*)[13] and that rely to a higher extent on *in-house R&D* (as compared to externally contracted R&D activities) are pursuing, in general, innovations of higher quality and scope and, thus, more prone to apply for international patents (see, e.g., Beneito 2006; Añón-Higón 2016).[14] Finally, according to Czarnitzki et al. (2009), basic research may be expected to have a higher impact on the propensity to patent and, therefore, we also include the variable *Basic R&D* defined as the percentage of total R&D expenditures on basic research (as compared to applied development).

Additionally, the vector c_{it3} in Eq. (1) represents a set of firm control variables for other factors that might bias our results if excluded, since they are likely associated with firms' decisions to patent abroad and also with some of the explanatory variables of interest just mentioned. First, we include a set of variables that could proxy for better access to foreign markets and so positively affect the propensity of patenting abroad. These variables account for the percentage of external R&D purchased from abroad to different organizations, such as firms in the same group, other firms, and universities (variables *Ex_R&D_1*, *Ex_R&D_2* and *Ex_R&D_3*, respectively). Second, we include three variables to control for financial and liquidity constraints: one is the size of the firm (*Log_employees*) and the other two are dummy variables for group affiliation (*Group*) and for foreign capital participation (*Fore_capital*). These two latest variables acknowledge the potential existence of an internal capital

[13] Although the percentage of PhD holders could be also capturing the high technological level of the sector where firms operate, we expect this effect to be controlled for with the industry dummies included in estimation.

[14] See Beneito (2006) for arguments that support the different characteristics of the R&D projects undertaken by firms pursuing innovations of more radical nature as compared to those of more incremental content. In particular, the author finds that in-house developed R&D is significantly more conductive to radical innovations than externally contracted R&D. Also more recently, Añón-Higón (2016) finds that conducting internal basic research helps firms to bring new products into the market ahead of competitors, and contributes to innovation performance.

Table 4 Summary statistics

Variables	(1) All patents sample means (SD)	(2) International patents sample means (SD)	(3) Spanish Office patents sample means (SD)
Yes_patents_abroad	0.563 (0.496)	1.000 (0.000)	0.000 (0.000)
Yes_patents_EPO	0.384 (0.486)	0.682 (0.466)	0.000 (0.000)
Yes_patents_USPTO	0.163 (0.370)	0.290 (0.454)	0.000 (0.000)
Yes_patents_PCT	0.289 (0.453)	0.512 (0.500)	0.000 (0.000)
Patents_abroad (proportion)	0.424 (0.425)	0.753 (0.271)	0.000 (0.000)
Patents_EPO (proportion)	0.210 (0.327)	0.372 (0.360)	0.000 (0.000)
Patents_USPTO (proportion)	0.058 (0.168)	0.103 (0.213)	0.000 (0.000)
Patents_PCT (proportion)	0.157 (0.305)	0.278 (0.362)	0.000 (0.000)
Exports	27.870 (28.645)	33.166 (29.704)	21.037 (25.658)
Exp_EU	0.826 (0.379)	0.874 (0.332)	0.765 (0.424)
Exp_RoW	0.709 (0.454)	0.774 (0.418)	0.625 (0.484)
New_markets	3.240 (0.933)	3.283 (0.900)	3.184 (0.971)
Gain_share	3.197 (0.937)	3.250 (0.911)	3.129 (0.965)
Product innov.	0.828 (0.378)	0.847 (0.360)	0.802 (0.398)
Process innov.	0.715 (0.451)	0.727 (0.446)	0.700 (0.458)
Sales_innov_firm	15.794 (20.125)	16.051 (19.816)	15.464 (20.515)
Sales_innov_market	18.223 (23.055)	19.216 (23.843)	16.942 (21.936)
R&D_intens.	35.346 (26.125)	37.622 (25.920)	32.410 (26.100)
PhD. in R&D	5.605 (11.204)	7.058 (12.078)	3.731 (9.648)
In-house R&D	87.671 (16.460)	86.922 (17.006)	88.637 (15.678)
Basic R&D	3.098 (8.258)	3.594 (9.301)	2.458 (6.622)
Ex_R&D_1	1.501 (9.283)	2.103 (10.821)	0.725 (6.727)
Ex_R&D_2	3.594 (11.656)	4.475 (12.821)	2.457 (9.839)
Ex_R&D_3	0.418 (3.249)	0.563 (3.765)	0.231 (2.415)
Fore_capital	0.186 (0.389)	0.230 (0.421)	0.129 (0.336)
Group	0.512 (0.500)	0.584 (0.493)	0.419 (0.493)
Log_employees	4.480 (1.635)	4.648 (1.594)	4.264 (1.662)
Young_firm	0.182 (0.386)	0.191 (0.393)	0.171 (0.377)
Observations	5400	3042	2358

market, although they may also account for better access to international markets, especially if group affiliation acts partially as a proxy for multinational firm. Finally, and once controlled for the ease of access to finance, we include a dummy variable identifying young firms (the ones born after the year 2000, variable *Young_firm*) that may capture the different patenting dynamism associated to the firm's age.

To conclude with the right hand side elements in Eq. (1), we also include a full set of year (λ_t) and two-digit industry dummies (λ_j). They will control, respectively, for macroeconomic conditions and for firms' differences in patent internationalization strategies influenced by the technological level of industries where they operate.

Table 5 Probability of international patenting (marginal effects)

	Probit	Multivariate probit		
	(1) ALL international patents	(2) EPO patents	(3) USPTO patents	(4) PCT patents
Exports	0.002*** (0.000)	0.001*** (0.000)	0.002*** (0.000)	0.001** (0.000)
Exp_EU	0.064** (0.028)	0.054* (0.028)	0.011 (0.022)	0.024 (0.027)
Exp_RoW	0.046* (0.025)	0.041* (0.025)	0.047*** (0.017)	0.016 (0.023)
New_markets	0.009 (0.011)	− 0.014 (0.012)	− 0.015* (0.009)	0.014 (0.011)
Gain_share	0.005 (0.011)	0.023* (0.012)	0.015* (0.009)	0.004 (0.011)
Product innov.	0.034 (0.025)	0.049** (0.024)	− 0.001 (0.018)	− 0.001 (0.023)
Process innov.	0.003 (0.019)	0.003 (0.019)	− 0.042*** (0.015)	− 0.011 (0.019)
Sales_innov_firm	− 0.000 (0.000)	− 0.000 (0.000)	− 0.000 (0.000)	0.000 (0.000)
Sales_innov_market	0.001** (0.000)	0.000 (0.000)	0.001*** (0.000)	0.001** (0.000)
R&D_intens.	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.001*** (0.000)
PhD. in R&D	0.004*** (0.001)	0.002** (0.001)	0.003*** (0.001)	0.002*** (0.001)
In-house R&D	− 0.000 (0.001)	0.000 (0.001)	0.000 (0.000)	− 0.001 (0.001)
Basic R&D	0.002* (0.001)	0.004*** (0.001)	0.002*** (0.001)	0.002 (0.000)
Ex_R&D_1	0.001 (0.001)	0.000 (0.001)	0.001 (0.001)	− 0.000 (0.001)
Ex_R&D_2	0.001 (0.001)	0.001** (0.001)	0.001 (0.001)	0.000 (0.001)
Ex_R&D_3	0.004 (0.003)	− 0.001 (0.002)	0.001 (0.001)	0.004* (0.003)
Fore_capital	0.035 (0.027)	0.015 (0.026)	− 0.008 (0.018)	− 0.023 (0.024)
Group	0.103*** (0.023)	0.068*** (0.023)	0.062*** (0.016)	0.069*** (0.021)
Log_employees	0.014* (0.008)	0.029*** (0.008)	0.023*** (0.006)	0.023*** (0.008)
Young firm	0.035 (0.029)	0.020 (0.030)	0.041* (0.022)	0.019 (0.027)
Log likelihood	− 3289.69	− 8015.82	− 8015.82	− 8015.82
Observations	5400	5400	5400	5400

Correlation coefficients: $\rho_{EPO,USPTO} = 0.535$***; $\rho_{EPO,PCT} = 0.065$**; $\rho_{USPTO,PCT} = 0.350$***. Firm-clustered errors in parentheses (1869 clusters = firms)

***p < 0.01, **p < 0.05, *p < 0.1

In Table 1 we present the distribution of patent applications by the type of patent office. Patent applications registered in the Spanish Patents and Trademarks Office (SPTO) represent around 57% of all applications, followed by EPO patents (about 21%), PCT patents (about 16%), and USPTO patents (about 6%). Hence, patent applications abroad sum up around 43%. The overall average number of patent applications per firm and year is slightly above 2.

As there may be firms filing for patents simultaneously in more than one patent office, Table 2 illustrates the correlation coefficients among five dummy variables with value one whenever a firm files for patents in the SPTO, in any of the foreign patent offices considered (we label this case 'abroad' in the table) and, then, in the EPO, in the USPTO, and/or the PCT.[15] The table shows that applying for

[15] Firms are asked to report the total number of different patent applications and the patent applications in each patent office. Unfortunately, when reporting the number of patents to the different patent offices, we do not have information on whether these patent applications refer to the same invention or not, and this lack of information could explain part of the simultaneity of patent applications in different patent offices.

Table 6 International patenting by destiny (Logit transformation)

Variables	Multivariate logit-transformed shares			
	(1)	(2)	(3)	(4)
	ALL	EPO	USPTO	PCT
Exports	0.048*** (0.008)	0.020*** (0.007)	0.027*** (0.005)	0.016** (0.007)
Exp_EU	1.119** (0.530)	0.694* (0.394)	0.127 (0.235)	0.315 (0.428)
Exp_RoW	0.784 (0.489)	0.623 (0.381)	0.491** (0.220)	− 0.061 (0.356)
New_markets	0.017 (0.216)	− 0.265 (0.176)	− 0.226** (0.106)	0.253 (0.169)
Gain_share	0.114 (0.218)	0.216 (0.179)	0.182* (0.107)	− 0.010 (0.176)
Product innov.	0.588 (0.474)	0.825** (0.378)	− 0.118 (0.213)	− 0.108 (0.369)
Process innov.	− 0.088 (0.370)	0.183 (0.303)	− 0.533*** (0.178)	− 0.105 (0.303)
Sales_innov_firm	− 0.006 (0.009)	− 0.006 (0.008)	0.000 (0.004)	0.000 (0.007)
Sales_innov_market	0.010 (0.008)	− 0.006 (0.007)	0.018*** (0.005)	0.009 (0.006)
R&D_intens.	− 0.001 (0.008)	− 0.003 (0.006)	− 0.001 (0.004)	0.012** (0.006)
PhD. in R&D	0.080*** (0.021)	0.021 (0.014)	0.038*** (0.012)	0.044** (0.018)
In-house R&D	0.001 (0.012)	0.004 (0.010)	0.004 (0.005)	− 0.011 (0.010)
Basic R&D	0.042* (0.022)	0.046*** (0.017)	0.030** (0.013)	0.014 (0.019)
Ex_R&D_1	0.029 (0.019)	0.012 (0.021)	0.023* (0.013)	0.005 (0.019)
Ex_R&D_2	0.023 (0.016)	0.033** (0.016)	0.015 (0.011)	− 0.014 (0.011)
Ex_R&D_3	0.057 (0.051)	− 0.023 (0.037)	0.009 (0.024)	0.056 (0.045)
Fore_capital	1.624*** (0.540)	0.961** (0.459)	0.103 (0.313)	0.035 (0.444)
Group	2.096*** (0.446)	0.891** (0.368)	0.728*** (0.208)	0.974*** (0.352)
Log_employees	0.006 (0.152)	0.208 (0.129)	0.182** (0.077)	0.086 (0.115)
Young firm	0.558 (0.559)	− 0.066 (0.432)	0.412 (0.286)	0.489 (0.460)
Constant	− 9.441*** (1.609)	− 8.836*** (1.553)	− 13.301*** (0.485)	− 13.344*** (0.839)
Log likelihood	− 19394.65		− 52020.72	
Observations	5400	5400	5400	5400

Correlation coefficients: $\rho_{EPO,USPTO} = 0.041$**; $\rho_{EPO,PCT} = -0.185$***; $\rho_{USPTO,PCT} = 0.005$. Firm-clustered errors in parentheses (1869 clusters = firms)

***p < 0.01, **p < 0.05, *p < 0.1

patents in a foreign office is positively correlated with patent applications in other foreign offices. In particular, the highest pairwise correlation is found between EPO and USPTO patent applications (around 0.34), followed by the correlation between USPTO and PCT patent applications (around 0.26). The lowest is obtained between EPO and PCT patent applications (around 0.11). Furthermore, there is a negative and also statistically significant correlation coefficient (around − 0.53) between firms' patent applications abroad and its patent applications in the SPTO. This result could be explained on the basis of the trends observed in Fig. 1, where it seems that over the period considered, the number of Spanish firms patenting abroad has increased while firms patenting domestically show a somewhat decreasing trend.

However, results are somehow different when correlation coefficients are calculated with the number of patent applications in different patent offices. In this case, Table 3 indicates that there is always a positive correlation between the number of patent applications in different offices, even between the domestic and the foreign offices. This result could be reconciled with the one above mentioned if the number of patent applications has generally increased in all patent offices, but the frequency of firms choosing to file for a patent abroad has been relatively larger.

In addition, if we further construct excluding categories of patent applications by patent offices, we obtain that around 44% observations (2358) correspond to firms that only apply for patents in the Spanish office, around 26% (1431) to firms that only apply for patents abroad, and around 30% (1611) to firms that apply for patents both in the Spanish office and abroad. Among the latter group, 33% of total observations correspond to firms that only apply for patents in the EPO office, followed by EPO-USPTO-PCT applications (20%) and only PCT applications (18%), by firms applying both to EPO and PCT or to EPO and USPTO (13 and 11%, respectively) and, finally, in a much lower proportion, by firms applying to USPTO and PCT or only to USPTO (2 and 3%, respectively). The figures are reasonably comparable if we attend to the group of firms that only apply for patents abroad: 39% of observations correspond to EPO applications only, 6% to USPTO, 33% to PCT, 5% to EPO and USPTO, 8% to EPO and PCT, 2% to USPTO and PCT, and 7% to EPO, USPTO and PCT.

In Table 4 we present summary statistics of patent applications and the rest of variables involved in our econometric analysis.

Amongst the market variables, we observe in Table 4 that, as compared to firms applying for patents only in the Spanish office, those applying for patents abroad have higher export intensity (around 33% against 21%), are more likely to export to the EU and to the rest of the world, and assess more often that penetrating new markets and gaining market share are relevant goals of innovation. Firms might be interested in patenting at the patent offices covering the areas to which they export. This may indicate that property rights have a role in trade. Our data thus reproduces something already documented by the literature (see, e.g. Licht and Zoz 1998), that is, that the pattern of firms' international patenting is likely to be similar to the pattern of firms' exports.

Summary statistics for the group of variables characterizing the innovation type and quality indicate that firms applying for patents abroad are slightly more likely to introduce product and process innovations, have higher percentage of sales from products that are new to the market (about 19% against 17%),[16] higher percentage of workers employed in in-house R&D (about 38% against 32%), higher percentage (over total employment) of in-house R&D workers who hold a PhD degree (about 7% against 4%), lower proportion of internal R&D expenditures (about 87% against 89%), and higher proportion of basic R&D research (about 4% against 2%).

Table 4 also shows that firms applying for patents abroad (with respect to firms only applying in the Spanish office) have higher percentage of external

[16] The percentage of sales from products that are new to the firm but not to the market is also slightly higher for firms applying for patents abroad.

R&D from organizations in other countries than Spain, they are more likely to be participated by foreign capital and to belong to a group, and they are on average larger and slightly younger firms.

3 Econometric results

Tables 5 and 6 display the main econometric results of our paper. In the first column of both tables we estimate Eq. (1) where the dependent variable represents international patenting without distinguishing the office where the application for the patent has been filled. In Table 5 the dependent variable is a dichotomous indicator taking the value of 1 if the firm has applied for any patent abroad during the current and the previous 2 years, and zero otherwise. In Table 6 we use instead a quantitative variable measuring the share of foreign patent applications (that is, the number of international applications over total patent applications). In the rest of columns of Tables 5 and 6 (columns 2–4), we distinguish between USPTO, EPO and PCT patents, defining dichotomous indicators for each of them in Table 5, and the corresponding shares of patents in each office in Table 6.

Given the dichotomous nature of the dependent variables in Table 5, we apply *probit* estimation in this case. Thus, we estimate the likelihood of patenting abroad as a function of all the explanatory variables of the model. In the first column, as indicated above, we consider a unique indicator of international patenting activity, so that we apply a single equation probit model in this case. However, we apply a multivariate *probit* to the indicators of patenting activity in USPTO, EPO and PCT, to account for the possibility that firms' decisions to apply for patents in different offices might be mutually related. As discussed earlier, when applying for patents abroad, Spanish firms may take different routes, depending on the country coverage they want to seek protection, and these routes are not exclusive. First, if they want to seek for protection at the European level, that is, in several European countries, they may want to file applications to the EPO. When firms want to seek protection of inventions in the US market, they may file patent applications in the USPTO. Finally, when firms want to seek protection more generally at an international level, that is, in a broader coverage of countries, they may want to file an application for a PCT patent, which is valid in more than 140 contracting countries and which provides the applicant with a further delay before entering into expensive national or regional phases. However, firms may be interested in filing applications simultaneously in different patent offices when they want to seek maximum protection for an invention of high value.[17] Thus, in this case, we estimate jointly three equations of the type of Eq. (1), corresponding to the three patent offices considered, and allow their error terms to be correlated.

[17] Note that EPO, USPTO and PCT patents may be considered as covering three different geographical areas, namely, Europe, US and the rest of the world, respectively, and, therefore, we could think of them as different international strategies that Spanish firms may follow when deciding to apply for patents abroad.

A first observation in Table 5 corresponds to the estimated coefficients of the trade indicators. In column 1, both the export share and the dummy indicators of export destiny, either the EU or the rest of the world (RoW hereafter), are positive and statistically significant (although less so for the RoW dummy). Thus, the degree of openness of the firm seems to be a factor contributing to the probability of international patenting, although the dummy indicators do not allow us to disentangle at this level if one or another export destiny is more or less related to a given patent office. These results are in line with existing literature linking international patenting to international trade, documenting that the propensity to patent abroad is positively related to exports (see, e.g., Eaton and Kortum 1996; Licht and Zoz 1998; Guellec and van Pottlesberghe de la Potterie 2001; Yang and Kuo 2008).

Interestingly enough, if we attend to the results in columns 2–4, we observe that firms exporting both to the EU and to the RoW have a statistically significant higher probability of EPO patent applications, with a higher coefficient in the first case. On the other hand, the RoW markets are more connected with USPTO patent applications, whereas firms exporting to the EU do not exhibit a significantly higher probability of filling for patents in the US. Finally, PCT patents do not seem to be specially affected by any destiny in particular. These findings contribute to the idea that firms' product markets and innovation protection are geographically coincident, at least to some extent.

The other two variables capturing market-oriented factors, *New_markets* and *Gain_share*, do not render statistical significance in column 1. However, when looking at the multivariate probit results, it seems that firms aiming at gaining market share are more prone to apply for both EPO and USPTO patents, while firms seeking to access new markets seem to be negatively related to patent applications in EPO and USPTO, although the effect is only marginally significant in the latter case. These results would be suggesting that international patenting activity, at least in EPO and USPTO offices, seems to be oriented to enlarge the market share of firms already operating in these markets, whereas the exploration of new markets plays a less relevant role when applying for patents in these geographical areas. The positive sign of the estimated coefficient for the *New_markets* dummy in the equation for PCT applications, although not statistically significant, might be indicating that the exploration of new markets has more to do with patents in other areas than Europe or the US.

The following effects of interest are those corresponding to the variables capturing the type and quality of the innovation. In column 1, three variables stand out as exerting a significant impact on firms' international patenting. The first of these variables is the percentage of the firm's sales corresponding to products that are not only new to the firm but also new to the market, whose effect is positive and significantly estimated. In the multivariate probit estimation, distinguishing among the different patent offices, we find that this effect corresponds to USPTO and PCT applications, while the effect is not found to be significant for EPO applications.

The second of the variables in this group is the percentage of employees holding a PhD degree over the total number of R&D employees of the firm, whose estimated effect is also positive and statistically significant. To the extent that

R&D labs with a higher percentage of PhDs are associated with higher scope and quality of the pursued innovations, we could infer from this result that the higher the quality of the innovation, the higher the probability of patenting abroad. When distinguishing among patent offices, this finding seems to apply to the three cases considered.

Finally, firms undertaking more basic research are more prone to patent abroad, although this result holds at a 10% level of significance. This finding emerges even clearer in the multivariate probit estimation, where the positive impact of basic R&D is found to affect EPO and USPTO applications, but not PCT applications. Although basic R&D is less related to the market than more applied research and development, this could be indicating that, apart from market considerations, firms may be interested in registering their patents in other international patent offices for strategic considerations. For example, firms may seek to protect basic innovations that might serve as a first step to subsequent findings that could build on such initial achievements. Patent thickets, particularly important in complex technologies, are an example of such patenting strategies (see, e.g., Graevenitz et al. 2013).

The multivariate probit estimation also allows us to capture some effects that remain not statistically identified in the aggregate measure in column 1. For instance, firms with product innovations are significantly more likely to apply for patents in the EPO office, whereas firms with process innovations explain a lower probability of USPTO applications. This result is in line with the idea that product patents are typically considered stronger property rights than process patents, allowing for a more effective blocking of entry by potential competitors (see, e.g., Cockburn et al. 2016). Also, the multivariate probit allows us to find a positive and significant effect of R&D intensity in the case of PCT patents.

Other variables, as presented in Eq. (1), are also included to capture other dimensions of firms that might be affecting international patenting decisions. For instance, firms that are active in R&D offshoring activities may have an international experience in foreign markets that can make them more prone to patent abroad. We obtain that firms purchasing R&D services from other firms in other countries (*Ex_R&D_2*) tend to apply more for EPO patents while firms buying R&D from universities in other countries (*Ex_R&D_3*) are positive and significantly associated with a higher probability of PCT patents. We interpret these findings as suggesting that the purchase of R&D services may be considered as a complementary innovation activity helping firms in their international patenting decision.

Finally, firms belonging to a group, as well as larger firms, seem to be more prone to patent abroad, results that hold irrespective of the particular patent office we look at. The finding of a positive link between firm size and propensity to patent abroad has already been documented in the literature (see, e.g., Licht and Zoz 1998, for a sample of German firms; or Sirilli 1987, for a sample of Italian firms). On the other hand, younger firms seem to be somewhat more prone to apply for patents in the USPTO.

A final comment on Table 5 is the significant correlation between the three equations in the multivariate probit, the highest of these correlations being that between EPO and USPTO patents, followed by the correlation between USPTO and PCT patents and, to a much lower extent, between EPO and PCT patents.

Next, in Table 6 we present the econometric results corresponding to model (1) with quantitative dependent variables, that is, with the dependent variable defined as the percentage of international patent applications registered by the firm (column 1), and the percentage of EPO, USPTO and PCT patents (columns 2–4). To deal with the nature of the dependent variables in this case, we assume a *logit-linear* distribution and, accordingly, we apply the logit transformation to the original proportions.[18] Thus, we estimate a model similar to the one defined in Eq. (1) but with a logit transformed dependent variable as follows:

$$\log\left(\frac{n_{it3}}{1-n_{it3}}\right) = \alpha + \beta\, m_{it3} + \gamma\, q_{it3} + \delta\, c_{it3} + \lambda_t + \lambda_j + \nu_{it3} \tag{2}$$

where n_{it3} stands for the proportion of patent applications in any of the international offices considered or, alternatively, in each one of them. In the first case, after logit-transforming the dependent variable, we apply OLS, whereas we apply multivariate OLS estimation to estimate jointly the logit-transformed proportions of EPO, USPTO and PCT patent applications.

The results in Table 6, in terms of estimated signs and significance of the effects of interest, confirm to a considerable extent the findings of Table 5. The quantitative version of the dependent variables in this case, however, allows us to quantify some of the previous results. For interpretation purposes of the estimated coefficients, the logit-linear model for a proportional dependent variable can be thought of as a log-linear model for a ratio dependent variable of the *in-group* (international patents, in our case) to the *out-group* (all the rest of patents).[19] For example, the estimated coefficient for *Exports* in column 1, would be indicating that an increase of, say, 10% points in the export propensity, explains an increase of near 62% in the ratio of international patents to domestic patents of the firm. Moreover, and according to the estimated coefficients of the multivariate model, the destiny of the firm's main export market being the EU almost doubles the ratio of EPO patent applications to the rest of patent applications (as compared to firms that do not export to this market). On the other hand, firms exporting to RoW countries have, according to our results, ratios of USPTO patent applications to the rest, that are around 63% higher than those of firms exporting elsewhere in the world. In this quantitative version of our estimation model, the destiny of exports being the RoW, does not have a significant effect on EPO patents.

[18] If a proportional variable y is assumed to be logit-linear, then its logit transformation is assumed to be normally distributed $\log(\frac{y}{1-y}) \sim N(\mu, \sigma^2)$. The logit transformation only works for values that fall between zero and one. Zeros and ones are undefined. Thus, we need to 'winsorize' these observations, making all of them slightly more than zero and slightly less than one.

[19] Assume n_{it} stands for the proportion of the firm's total number of patents that have been applied for in EPO in that period. Then, if β is the coefficient associated to a given explanatory variable x, it follows that: $\Delta\%(\frac{EPOpatents}{non\text{-}EPOpatents}) = (\exp(\beta \cdot \Delta x) - 1) \times 100$.

Continuing with the group of market-type variables, the estimated coefficients of *New_markets* and *Gain_share* render the same signs in the multivariate estimation in Table 6 than in Table 5, although now the impacts are only significant in the case of USPTO patents. Again, it emerges clearly the idea that firms patenting in USPTO are more focused on increasing their market share in those markets (positive effects of around 20% in the ratio of USPTO to the rest), and less so in exploring new markets in these areas (negative effects of around 20%). In this case, unlike in Table 5, these variables do not significantly explain different ratios of EPO patents.

With regards to the variables indicating innovation quality, one difference to be made is that corresponding to the positive impact of PhD holders within the R&D programs of the firms, which now is only significantly captured for USPTO and PCT patent applications. The effects indicate that, for example, an increase of 10% points in the share of PhDs in its R&D lab would increase its ratios of USPTO or PCT patent applications to the rest by around 46 and 55%, respectively. These results are in line with the hypothesis that the higher the quality of the R&D projects, at least to the extent that they rely on more qualified human capital, the higher the internationalization of patents, and, in particular, the higher the ratios of USPTO and PCT patent applications to the rest. The effects are not only statistically significant, but also quantitatively considerable.

The rest of variables of the model also seem to confirm the estimated signs in Table 5. Perhaps a difference to notice is that, in this version of the model, the purchase of R&D services abroad from other firms of the same group seems to facilitate UPSTO patents, whereas no significant effect was found in this case in Table 5. In addition, the effect of foreign capital is now also statistically significant and positive in the case of EPO patents (ratios of EPO patents to the rest around 161% higher than for firms without foreign capital participation).

The positive impact of belonging to a group of firms is again confirmed, with estimated values indicating that firms affiliated to a group have international patent application ratios that range from 107 to 165% higher than otherwise, the greatest of these effects being found in the case of PCT patent applications.

Finally, and regarding correlations among equations in this case, results confirm the significant correlation between EPO and USPTO patents, while EPO and PCT patents seem to be negatively correlated. This latter result indicates, then, that unobservable factors inducing firms to apply for a higher proportion of their patents through, say, the PCT system, tend simultaneously to decrease the proportion of applications in the European office.

4 Concluding remarks

During the last decades, an increasing trend towards international patenting has been observed in many countries. In this paper we provide an empirical investigation into the determinants of firms' decisions to apply for patents abroad,

distinguishing among EPO, USPTO and PCT patents, using a panel dataset of Spanish innovative firms for the period 2005–2013. Our results show that the propensity of Spanish firms to patent abroad is positively associated with trade-related factors, namely, the volume of exports and exports destiny. In particular, firms exporting to the European Union are more likely to apply for patents in the EPO, whereas firms that mainly export to the rest of the world apply more often to USPTO. Second, we obtain that international patenting in EPO and USPTO seems to be more oriented towards market enlargement than to accessing new markets. Third, our results suggest that a number of factors capturing the quality and the scope of innovations are positively associated with the propensity to patent abroad, such as the quality of the workforce, measured by the percentage of Ph.D. holders in the R&D workforce, whether firms introduce product innovations, innovative sales from new products to the market, and basic research.

If international patenting may be considered as one of the main sources of international diffusion of new products and processes and also a major force for a country's productivity growth and international competitiveness, our findings suggest the following policy implications. First, international patenting seems to be primarily associated with international trade. Thus, the promotion of innovative activities by firms should go hand in hand with policies to foster international trade and, in particular, to create incentives for firms to increase their presence in international markets. Second, firms are more prone to patent abroad the higher the scope and quality of the innovations they seek to protect. Then, by promoting firms innovative activities, especially those of higher innovative content, policy makers may help stimulating international diffusion of knowledge and technology, contributing not only to their own economic growth but also to the economic growth of nations.

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Appendix

See Table 7.

Table 7 Variable names and definitions

Exports	Volume of exports (percentage over firm's sales), calculated as the average over three periods (t + (t − 1) + (t − 2))/3
Exp_EU	Dummy variable equal to one (and zero otherwise) if the firm exports to countries of the European Union, European Free Trade Association (EFTA) or EU candidate countries. The question in the survey corresponds to the current (t) and the previous 2 years
Exp_RoW	Dummy variable equal to one (and zero otherwise) if the firm exports to countries other than those mentioned in *Exp_EU*. The question in the survey corresponds to the current (t) and the previous 2 years
New_markets	Discrete variable from 1 to 4 rating the firm' assessment on how important is to penetrate new markets as a goal of innovation. The question in the survey corresponds to the current (t) and the previous 2 years
Gain_share	Discrete variable from 1 to 4 rating the firm' assessment on how important is to gain market share as a goal of innovation. The question in the survey corresponds to the current (t) and the previous 2 years
Product innov.	Dummy variable equal to one (and zero otherwise) if the firm introduced a product innovation during the current (t) and the previous 2 years
Process innov.	Dummy variable equal to one (and zero otherwise) if the firm introduced a process innovation during the current (t) and the previous 2 years
Sales_innov_firm	Percentage of firm's turnover corresponding to products that are new for the firm (but not new in the market), calculated as the average over three periods (t + (t − 1) + (t − 2))/3
Sales_innov_market	Percentage of firm's turnover corresponding to products that are new in the market, calculated as the average over three periods (t + (t − 1) + (t − 2))/3
R&D_intens.	Percentage over total workers (full time equivalents) employed in in-house R&D, calculated as the average over three periods ((t − 1) + (t − 2) + (t − 3))/3
PhD. in R&D	Percentage of total workers (full time equivalents) employed in-house R&D that hold a PhD degree, calculated as the average over three periods ((t − 1) + (t − 2) + (t − 3))/3
In-house R&D	Internal R&D expenditures (percentage over total R&D expenditures), calculated as the average over three periods ((t − 1) + (t − 2) + (t − 3))/3
Basic R&D	R&D expenditures on basic research (percentage over total R&D), calculated as the average over three periods ((t − 1) + (t − 2) + (t − 3))/3
Ex_R&D_1	Purchase of R&D services from firms of the firm's own group in other countries (percentage over total external R&D), calculated as the average over three periods ((t − 1) + (t − 2) + (t − 3))/3
Ex_R&D_2	Purchase of R&D services from other firms in other countries (percentage over total external R&D), calculated as the average over three periods ((t − 1) + (t − 2) + (t − 3))/3
Ex_R&D_3	Purchase of R&D services from universities in other countries (percentage over total external R&D), calculated as the average over three periods ((t − 1) + (t − 2) + (t − 3))/3
Fore_capital	Dummy variable taking value one (and zero otherwise) if the firm has foreign capital participation in t
Group	Dummy variable taking value one (and zero otherwise) if the firm belongs to a group of firms in t
Log_employees	Log of the firm's number of employees (full time equivalents), calculated as the average over three periods (t + (t − 1) + (t − 2))/3
Young firm	Dummy variable taking value one (and zero otherwise) if the firm was born after year 2000

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