European Commission

JRC TECHNICAL REPORTS

Intellectual Property Protection Mechanisms and the Characteristics of Founding Teams

JRC Working Papers on Corporate R&D and Innovation No 01/2019

Sara Amoroso and Albert N. Link

2019

Joint Research Centre

Contact information
Sara Amoroso
Address: Edificio Expo. c/ Inca Garcilaso, 3. E-41092 Seville (Spain)
E-mail: jrc-b3-secretariat@ec.europa.eu
Tel.: +34 954488463
Fax: +34 954488316

JRC Science Hub
https://ec.europa.eu/jrc

JRC113094

ISSN 1831-9408 (online)

Seville, Spain: European Commission, 2019

How to cite: Amoroso, S. and Link, A. N. (2019). Intellectual Property Protection Mechanisms and the Characteristics of Founding Teams, JRC Working Papers on Corporate R&D and Innovation No 01/2019, Joint Research Centre.

The **JRC Working Papers on Corporate R&D and Innovation** are published under the editorial supervision of Sara Amoroso in collaboration with Antonio Vezzani, Andries Brandsma, Fernando Hervás, Koen Jonkers, Pietro Moncada-Paternò-Castello, Alexander Tübke and Daniel Vertesy at the European Commission – Joint Research Centre; Alex Coad (Pontificia Universidad Catolica del Peru), Michele Cincera (Solvay Brussels School of Economics and Management, Université Libre de Bruxelles); Enrico Santarelli (University of Bologna); Marco Vivarelli (Università Cattolica del Sacro Cuore, Milan).

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This Working Paper is issued in the context of the Global Industrial Research & Innovation Analyses (GLORIA) activities that are jointly carried out by the European Commission's Joint Research Centre (JRC) – directorate B, Growth and Innovation and the Directorate General Research and Innovation - Directorate A, Policy Development and Coordination.

Intellectual Property Protection Mechanisms and the Characteristics of Founding Teams[1]

Sara Amoroso

European Commission, Joint Research Centre, Seville, Spain

Albert N. Link

University of North Carolina at Greensboro, USA

Abstract

Intellectual property protection mechanisms (IPPMs) are critical to fostering innovation and their relevance has grown enormously with the increased trade in goods and services involving intellectual property. Scholars have investigated what factors facilitate or hinder the use of such IP protection strategies, identifying country, sector, and firm characteristics. However, the extant literature has overlooked the role of founding team characteristics on the choice of IPPMs. Using data from a large sample of European small and young entrepreneurial firms, we show that controlling for size, R&D intensity, and other firms and market effects, the founding team characteristics such as gender and education greatly influence the choice of IPPMs.

Keywords: IP choice, patents, appropriability, entrepreneurship, knowledge intensive firms, gender, AEGIS survey.

JEL Classification: M13; L26; O34.

[1] The authors wish to thank the participants to the workshop on challenges of innovation policy at Universitat Rovira i Virgili (Reus), Antonio Vezzani, Mafini Dosso, Emanuele Pugliese and Fernando Hervás (JRC Seville) for useful comments that helped us improve the paper. All remaining errors are our alone.

1. Introduction

One way for a firm to appropriate returns to its investments in research and development (R&D) and to protect its intellectual property is to adopt various intellectual property protection mechanisms (IPPMs). It is widely accepted that intellectual property (IP) is an important tool for economic growth, and policymakers have long considered the use of IPPMs as an effective way to protect and stimulate innovation. In addition, IPPMs, such as patents, can play an important role in business success. In fact, holding a patent may help entrepreneurs to access private equity financing from venture capitalists (Häussler et al. 2012; Graham et al. 2009). IPPMs such as patents have also been linked to greater market value among established businesses (Hall, Jaffe, and Trajtenberg 2005). To understand what factors play a role in the decision of using–and the choice of–IPPMs, we look at both firms' characteristics and those of their founders. Indeed, we stand behind the WIPO (2014, Chapter 2) in believing that the fundamental driver behind any innovation process is the related human factor.

The empirical literature on the choice of IPPMs revolves around three main findings. First, the choice of IPPM(s) varies across firms and sectors, as well as across technologies and types of innovations. For example, formal IPPMs (mainly patents) are a common mechanism among large, R&D intensive firms that are product innovators and are not subject to financial constraints (Lanjouw and Schankerman, 2004; Hall et al., 2013; Veugelers and Schneider, 2017). However, large R&D firms in the semiconductor industry do not rely on patents to protect their innovations; rather, they engage in patent portfolio races to prove their technology independence to the market and to be better positioned when accessing external technologies (Hall and Zeidonis, 2001). Second, while theoretical studies have long treated formal and informal IPPMs as substitutes (Friedman et al. 1991), empirical evidence shows that there is some degree of complementarity between the different IPPMs (Landry et al., 2009; Gallié et Legros, 2012), reflecting the fact that firms rely on several protection mechanisms to protect different components of their increasingly complex and integrated innovations. The third recurrent empirical finding is that companies consider informal mechanisms more effective than formal ones to protect their innovations (Levin et al. 1987; Cohen et al. 2000; Arundel 2001). In particular, when firms need to protect large valuable investments, they tend resort on informal IPPMs, such as trade secrets or first mover advantage (Anton and Yao, 2004), to staving off free-riders (Hall et al., 2014).

While the literature on the choice of IPPMs principally looks at traditional firms' and sectoral characteristics[2], none of the previous studies has investigated the link between IPPMs and the characteristics of the founding team. Founding teams are composed of individuals with various characteristics (e.g., age, gender, educational background, nationality, working experience), and this team heterogeneity could provide insight on the diversity of uses of IPPMs. This might especially be the case among young, innovative startups in which the strategic activities of the firm, and hence its performance, are a direct reflection of the founders' characteristics and abilities. In fact, existing studies on the

[2]An exception is the study of Gallié and Legros (2012) which relate *human resources strategies* to the choice of IPPM and finds that human resource management influences firms' strategic choices and especially the choice of the means of IP protection. Indeed, employees' job mobility affects secrecy and the incentive to innovate (Cooper, 2001), resulting in efforts to control the communication flows between workers and the external environment.

relationship between founding teams and firm performance find that firms with diverse teams have higher levels of performance (Eesley et al. 2014), while firms with more educated founders that had prior experience in R&D are more likely to be innovate (Arvanitis and Stucki, 2012).

Through this paper, we contribute to the literature on the choice between formal and informal IPPMs by adding an additional layer to the analysis of the determinants of IPPMs. Indeed, controlling for country, sector, and firm characteristics, we investigate the compositional role of founding team—in terms of education, experience, age, nationality, and gender—in the adoption of different IP strategies using information from a large sample of European small and young entrepreneurial firms.

The remainder of this paper is outlined as follows. In Section 2, we review the existing literature related to the choice of IPPMs. In Section 3, we overview the AEGIS database and define the IPPM variables of interest of this paper. In Section 4, we discuss the variables used in our empirical estimation, and we present our empirical findings. The paper concludes in Section 5 with a summary of our findings and suggestions for future research.

2. Background studies

A patent gives the inventor monopoly privilege over an invention (i.e., complete and perfect appropriability) for a defined period of time, while at the same time a patent provides the full disclosure of technical information about the invention. There are thus two faces to a patent. One the one hand, it provides an incentive to the firm to invest in R&D, but on the other hand it dampens the impact of that incentive by disclosing technical knowledge albeit for the common good. The belief in the importance of patent protection has led scholars in economics to focus on the use of patents by firms as a means to appropriating returns to innovation (Schmookler, 1966; Comanor and Scherer, 1969). However, evidence based on firm surveys indicates that patents are not effective in protecting firms' most valuable innovation, especially when it is simple to invent around them, and that firms prefer to resort to other IPPMs to protect their innovations (Levin et al. 1987; Cohen et al. 2000; Arundel 2001). Gradually, the literature has shifted its focus from patents to other IPPMs and to a portfolio of IPPMs.

Hall et al. (2014) recently reviewed in detail the economic literature on the determinants of the choice among IPPMs. They found the choice to be firm-, sector-, and technology/innovation-specific. In their review, they distinguish between formal and informal IPPMs. Formal IPPMs are patents, trademarks and copyrights, while informal IPPMs are lead time, confidentiality agreements, design complexity, and trade secrecy.[3] Firms that choose formal IPPMs are typically large, product innovators, R&D intensive companies that have less financial constraints (Lanjouw and Schankerman, 2004; Hall et al., 2013). The choice of informal IPPMs depends on firms' competitive strategy, when for example they need to protect large, valuable innovations (Anton and Yao, 2004). However, firms rarely rely on only one IPPM, as they most likely choose a mix of formal and informal ones.

Veugelers and Schneider (2017) recently examined empirically alternative IP strategies adopted by young, innovative companies. Using data from the EUROSTAT Community

[3] Despite the label "informal", these types of IPPMs are often sealed by legally binding contracts, such as non-disclosure agreements which serve to protect trade secrets.

Innovation Survey (CIS) for Germany, the authors artfully place their research within the context of the broader economics and management literature related to appropriability strategy, and they offer new and insightful information about the choice of an IPPM. The authors conclude that (p. 1): "firms combining a young age and small scale with a high R&D intensive profile are more likely to use intellectual property (IP), specifically combining formal and informal appropriation mechanisms. They are especially more likely to choose secrecy in combination with formal IP."

The above referenced studies on appropriability mechanisms and firm-level innovation mainly focus on firm and sector characteristics without considering the explanatory potential of founding teams' characteristics. These characteristics might be relevant especially when looking at the IPPM choice of startups and small innovative firms. According to Arvanitis and Stucki (2012, p.1): "The innovative activity of start-ups might strongly depend on the characteristics of the firm founders, e.g. educational background and experience. The founders determine a firm's strategies and coordinate the resources to implement them … Further, as start-ups are mostly small firms, the capabilities of the founders themselves serve as important resources to create a competitive advantage … Founders do not only decide whether to innovate or not, but are directly involved in the innovation process of the start-ups."

The management literature has studied the relationship between founding team characteristics and firm performance without reaching a consensus (Nielsen, 2010). Firms with diverse teams (in terms of age, gender, and ethnicity) are likely to perform worse because of internal conflict; in contrast, diversity in education, professional background, and experience are conducive to greater innovate behavior (Williams and O'Reilly, 1998). Also, more diverse teams have higher levels of performance as they have access to a broader array of skills; but, more homogeneous teams tend to have faster execution and implementation (Eisenhardt and Schoonhoven, 1990; Beckman, 2006).

Eesley et al. (2014) suggest that the impact of diversity within a founding team on firm performance is tied to appropriability. In particular, when the appropriability regime is weak, firms will be more reluctant to partner for commercialization (i.e. cooperating) with the risk of disclosing legally non-appropriable knowledge, and they will decide to compete in the product market by themselves. To build the necessary capabilities to compete in the market, small and young firms typically have to invest their own assets. Their argument is that the more diverse the founding teams—educationally and professionally—the greater their advantage in building their own asset base because they have a wider range of skills. Using survey data on U.S. firms, these authors find that diversity of teams has a positive relationship with firm performance only when the IP regime is weak.

Other studies have looked at the intersection between founding team characteristics and innovation. For example, Arvanitis and Stucki (2012) find that for Swiss startups, the founder characteristics of education, prior experience in R&D, and strong motivation to innovate have a positive effect on the probability of commercialize innovative activities. More recently, Kristinsson et al. (2016) confirm that team diversity in education and experience is positively related to both the generation of ideas and thereof implementation into new products and services, provided they have a strategic approach to growth.

The Bort et al. (2017) analysis of 2,763 German startups from 10 different sectors shows that the effects of team diversity on innovation vary according to the type of diversity and on the type of product innovation (p.1): "While job-related team diversity benefits all types of innovation, national diversity does not facilitates global product innovations but instead the development of incremental as well as radical product innovations. Age diversity

decreases incremental product innovations while gender diversity decreases global product innovations."

In summary, the choice between formal, informal, or both IPPMs depends on the type of technology, the characteristics of the firm, and the sector it which it operates. While management studies have linked the characteristics of founding teams to the performance of small, entrepreneurial firms, the economic literature on IPPMs determinants does not report any evidence on the role of founding team characteristics for the choice of IPPMs. In this paper, we contribute to both the economic and management literatures by beginning to fill this void.

3. Data description

3.1 The AEGIS Database

The AEGIS (Advancing knowledge-intensive entrepreneurship and innovation for growth and social well-being in Europe) project was funded by the European Commission under Theme 8 "Socio-Economic Sciences and Humanities" of the 7th Framework Programme (FP7) for Research and Technological Development; the program lasted from 2007 until 2013. The project focused on knowledge intensive entrepreneurship (KIE), and this focus was based on the implicit assumption was that KIE is one potential means through which to obtain economic growth and societal well-being (PLANET, 2011).[4]

The AEGIS database contains information on 4,004 firms established between 2002 and 2007 across 10 European countries.[5] The AEGIS survey was conducted from late 2010 into 2012; at a minimum, a firm in the AEGIS sample would have been active for three years. The countries represented in the database are (alphabetically): Croatia, Czech Republic, Denmark, France, Germany, Greece, Italy, Portugal, Sweden, and the United Kingdom.[6] And, across these countries, a number of firms from the high-tech and low-tech sectors, and from the knowledge-intensive business services (KIBS) sector are represented in the database (but sectoral representation did not drive the construction of the database).[7, 8]

3.2 IPPM choices and founding team characteristics

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[4] "Knowledge-intensive entrepreneurship concerns new ventures that introduce innovations in the economic systems and that intensively use knowledge. From this broad definition, it follows that knowledge-intensive entrepreneurship may take place in various ways: through the foundation of new firms or through the display of entrepreneurial spirit with existing firms or through the action of single individuals within non-profit organizations such as universities or public laboratories" (Malerba, 2010, p.4).

[5] A complete description of the AEGIS database is in Caloghirou et al. (2011).

[6] The architects of the AEGIS database realized that firms in smaller countries would need to be over sampled. To account for non-random sampling across countries, sampling weights are used in the econometric analysis below. See Caloghirou et al. (2011) and Link and Swann (2016) on this issue.

[7] The high-tech sector includes aerospace; computers and office machinery; radio-television communication equipment; manufacture of medical, precision and optional instruments; pharmaceuticals; manufacturer of electrical machinery and apparatus, manufacturer of machinery and equipment, chemical industry. The low-tech sector includes paper and printing; textile and clothing; food, beverage and tobacco; wood and furniture; basic metals; fabricated metal products. The Knowledge-intensive business services (KIBS) sector includes telecommunications; computer and related activities; research and experimental development; selected business services activities.

[8] We have written about the AEGIS database numerous times so duplication of descriptive text is inevitable. See, for example, Amososo and Link (2018) and Audretsch et al. (2018).

Motivating this paper is one particular survey question on the AEGIS survey:

> *Please indicate [Yes or No] which of the following methods were used by your firm to protect its intellectual property during the last three years.*
>
> *1 Patents*
>
> *2 Trademarks*
>
> *3 Copyrights*
>
> *4 Confidentiality agreements*
>
> *5 Secrecy*
>
> *6 Lead-time advantages on competitors*
>
> *7 Complexity of design*

Figure 1 shows the average shares of firms that responded to the survey question that they used an IPPM within the last three years. Following the previous studies (Hall et al., 2014; Veugelers and Schneider, 2017), we label patents, trademarks, copyrights as formal IPPMs, while informal IPPMs include confidentiality agreement, secrecy, lead-time advantages on competitors, and complexity of design.[9] In general, a larger proportion of firms choose informal IPPMs, such as confidentiality agreements and lead time advantages, while only a small number of firms rely on patents and copyrights. Figure 2 shows the average shares of firms per number of IPPMs used. 43% of the sample does not use any IPPM, while the remainder 57% of firms uses largely 1 to 4 IPPMs at the same time.

Insert Figures 1 and 2 about here

The rates of use of the various IPPMs by IPPM category and sector group are reported in Table 1. In line with previous findings, high-tech manufacturing firms are the ones that use more IPPMs compared to firms in low-tech and knowledge intensive business service sectors. Also, in relative terms, high-tech firms rely more on formal IPPMs (especially trademarks) compared to other firms. Among the informal IPPMs, confidentiality agreements are the most often used, especially by KIBS firms (42% of 1982 firms).

Insert Table 1 about here

Tables 2 reports the cross-tabulations of the two dummy variables, formal and informal IPPM, that are equal to one if a firm has at least one formal or at least one informal IPPM, respectively. As already shown in Figure 2, 43% of firms do not use any IPPM, in great part because they do not have any innovative product or service to protect. Indeed 36% of the firms in the sample do not have a new product or service (Table 2). Only 7% of firms have a new product or service but decide not to use any IPPM.

[9] The IPPMs reported in the AEGIS survey match those on the CIS and were used by Veugelers and Schneider (2017), however confidentiality agreements were not on the CIS, but design and utility models were.

Insert Tables 2 and 3 about here

Altogether, these tables and figures show a great degree of heterogeneity in the use of IPPMs, and they support the evidence reported in previous studies that many firms have a preference for informal IPPMs or a combination of formal and informal IPPMs (Hall et al., 2014; Levin et al., 1987).[10]

3.1 Variables selection

While the IP literature identified a number of relevant firm characteristics that are related to the choice of formal and/or informal IPPMs, a less explored set of determinants that may influence the choices of young entrepreneurial firms are the characteristics of its founders. Studies on the relationship between founding team composition and firm performance indicate that demographic diversity (in terms of age, gender and ethnicity) is conducive for conflicts; background diversity, in terms of education and professional experience, is conducive for innovativeness (Williams and O'Reilly, 1998). With respect to the choice of IPPMs, one might expect that the more demographically diverse the founding team, the more difficult it will be to reach a consensus on which IPPM(s) is (are) best to use. However, background-diverse founders might build on those differences and thus have a clearer business strategy.

Founding team characteristics in the AEGIS database include the number of female founders, *Women*; the number of founders from another country, *International* founders; and the sum of years of previous work experience, *Experience*, in the same sector as their current business activity. The AEGIS database also allows measurement of whether the average team founder has at least a bachelor's degree, *Education*, or not. Given that firms in our sample might have been founded by a group of founders or by a single founder, we also control for the total number of founders (*Team size*).

Our a priori expectations of how selected characteristics of the founders might influence the choice of the use of IPPMs are as follows, other factors held constant. First, as female entrepreneurs have been shown to rely on IP per se at a lower rate than their male counterparts (WIPO, 2017), one might expect the number of women in a founding team to be negatively correlated with the probability of adopting an IPPM. Second, heterogeneity within the founding team, and in particular the difference in nationality, has been linked to increased innovation and creativity (Hambrik et al., 1998), which in turn we expect to stimulate the adoption of IPPMs. Third, founding teams that have more years of experience in the same business sector may be more familiar with the relative usefulness of alternative IPPMs, and thus they might rely on a larger set. And fourth, regarding education, Toivanen and Väänänen (2016) find a positive effect of university education on the propensity to patent, and thus we also expect to find educational attainment to be positively related to the use of formal IPPMs.

In line with previous studies, we consider a wide range of firm-level characteristics (Brower and Kleinknecht, 1999; Lanjouw and Schankerman, 2004; Hall et al., 2013; Veugelers and

[10] It is important to notice, however, that the available evidence relies on surveys where firms are asked to report whether they have formal IPPMs such as patents or use informal types protection mechanisms like lead time. In the first case, the use of patents can be verified, whereas reporting the use of first-mover advantage may be subjective to the respondent firm.

Schneider, 2017) as control variables. IP strategies vary across firms of different sizes, *Size*; larger firms have fewer financial constraints and are thus more likely to choose a portfolio of formal IPPMs as discussed above. *R&D intensity* is also generally associated with formal IPPMs (patents in particular). We also control for the share of sales from exports (i.e., *share international sales*), although we do not hypothesize the direction of the relationship larger share have with portfolios of IPPMs.

As for market characteristics, we include the presence of obstacles, such as technology or market *risk*. We conjecture that if a firm is uncertain about the possible market success of its new product, it will probably opt for an informal IP strategy as it is easier and less costly to implement.

We include a set of control variables that are new to this body of literature, each of which might influence the choice of IPPMs. In particular, we include a variable that proxies the *Dynamic environment* in which the firm operates, to test if the short life cycle of products and the dynamism of the market influence the choice of IPPMs. To test the hypothesis of Eesley et al. (2014), who suggested that firms cooperate only when they have a strong appropriability regime, we include a variable for the degree of cooperation among firms, *Cooperation*. Veer et al. (2016) also show that formal IP regimes work well at as mechanisms moderating the relationship between R&D cooperation and imitation, while informal IPPMs do not. Finally, we include a variable that controls for whether the market is dominated by price competition, *Competition*. We expect this variable to have a negative impact on the choice of any IPPM, because a firm in a market characterized by price competition will have a very limited monopoly position regardless of the IPPM used. Lastly, we control for country and 2-digit NACE sector fixed effects.

All the variables that we consider in our analysis are defined in Table 4, and the corresponding descriptive statistics are in Table 5, by category of IPPM (entire sample, only formal, only informal, both, or no IPPMs).

Insert Tables 4 and 5 about here

The left part of Table 5 reports means, standard deviations, and the ranges of values of all our variables for the entire sample. The right part of Table 5 shows only the averages by type of IPPM. Some stylized findings are evident from Table 5. Firms that rely on both formal and informal IPPMs (Both IP) have a significantly[11] larger number of international founders, they have a founding team that is on average more educated, while firms using only informal IPPMs were founded by a cumulatively more experienced team. In addition, firms with both IPPMs are significantly more involved in international trade; they are more R&D intensive, more cooperative, and more dynamic than firms that resort to formal or informal IP system alone. Finally, more than 50 percent of firms that rated the business environment as dominated by price competition adopt informal or no IPPMs.

4. Empirical analysis

[11] The results of t-tests with unequal sample size are not reported in Table 4, but they are discussed in the paper.

In our sample, there are no firms that use at least one IPPM and have no innovation (Table 3), indicating that IPPMs choices may be correlated with the decision to innovate. This is also intuitive as firms, in order to protect their innovations, must have some innovations first. Therefore, we employ a Heckman's two-step correction method to control for the non-random sampling bias deriving from to the fact that non-innovating firms do not use any IPPMs. The two-stage correction model is specified as follows:

$$S^* = z'\theta + \mu \quad ,$$
$$S = 1(S^* > 0),$$
$$Y^* = \begin{cases} 0 & if\ S = 0 \\ \alpha + x_i'\beta + control_i'\gamma + \varepsilon_i, & if\ S = 1 \end{cases}$$
$$Y = 1(Y^* > 0) \quad ,$$

where the selection indicator *S* takes value of 1 if a firm has introduced an innovation, while the IPPM choice indicator Y equals 1 only if the firm innovates. The vector *z* includes the R&D intensity, the R&D intensity per sector, the share of international sales, and sector fixed effects; x is the vector of founding team characteristics; $control$ is the vector of control variables described in section 3.3; we also control for country and 2-digit sector dummies.

Table 6 reports the expected changes in the probability of using at least one IPPM, for the whole sample and for manufacturing (high- and low-tech) and business service firms. Similarly to Leiponen and Byma (2009), we report differences between manufacturing and service firms, as previous literature has shown that service firms' strategies of appropriation may differ from those of manufacturing ones, because of the intangibility of services (Miles and Boden, 2000; Tether, 2005). The regression results suggest that some of the characteristics of the founding team matter for the choice of IPPM. In particular, the number of women in the founding team is negatively related to the probability of using informal IPPMs, while the education of the founders has a positive correlation with the choice of IPPMs.

Main differences between manufacturing and service firms are that the number of women has a negative effect on the probability of choosing IPPMs only among service firms, while the level of education matters only for manufacturing firms, specifically high-tech.

Insert Table 6 about here

The control variables confirm the findings of other studies. Being a large, R&D intensive, internationally engaged company is positively associated with the probability of using IPPMs. Moreover, cooperation has a positive relationship with the probability of adopting an IPPM, especially among service firms (Miozzo et al, 2016).

Table 7 shows the results for the marginal (unconditional) probabilities of using formal, informal or both types of IPPMs. As in the previous table, the characteristics that have a statistically significant association with the choice of IPPMs are the number of women in the founding team and the education of the team members. The number of women is negative related only to the probability of using informal IPPMs, while education is positively associated to formal IP or both types of IPPMs.

Insert Table 7 about here

Firms' characteristics are strongly associated with the probability of using IPPMs, with no significant differences across types. Market characteristics, on the other hand, have heterogeneous marginal effects on the probabilities of using formal/informal IPPMs. Indeed, if a firm operates in a risky business environment, the probability of using an informal IPPM increases by 2.4 percentage points, while a dynamic environment positively relates to the adoption of any IPPMs. Price competition is negatively related to the probability of using formal or both types of IPPMs, while it has a positive association with the probability of using an informal IPPM. Finally, cooperating with other firms results in an increased probability of adopting all types of IPPMs.

Table 8 reports the estimated marginal effects of a multivariate probit with sample selection correction to investigate the differences across the determinants of individual IP choices.

Insert Table 8 about here

The results show that a larger number of women in the founding team correspond to a lower probability of patenting. The presence of international founders has a positive effect on the probability of patenting, registering trademarks and using confidentiality agreements. Education is associated with an increase in the probability of using most IP systems (TMs, copyrights, trade secrets, and confidentiality agreements), however it has a negative relation with lead time advantage, pointing to the fact that less educated founding teams have a higher probability of choosing first mover advantage as protection of their innovations.

Among the firm and market characteristics, the higher the firm R&D intensity, the higher the probability of choosing informal IPPMs (a 1 percent increase in R&D intensity corresponds to an increase in probability of choosing any of the informal IPPMs of 0.13 to 0.16 percentage points). Also, the riskier the market, the higher the probability of choosing trade secrets, lead time or confidentiality agreements. A market characterized by price competition is associated with a decrease in the probability of choosing any formal IPPMs, and is positively related to the choice of first mover advantage. Cooperation with other firms has in general a positive impact on the probability of choosing most of IPPMs, especially TMs and confidentiality agreements.

5. Discussion and conclusions

IPPMs are important for fostering and protecting innovations, and their relevance has grown with the increased trade in goods and services involving IP. Using data from a survey conducted among 4,004 European SMEs, this study explores the role of founding team characteristics, in addition to firm and market characteristics, in relation to the choice of IPPMs. Our analysis provides a number of findings.

First, the probability of choosing any form of IP protection is negatively related to the number of female founders, especially among service companies. On the one hand, this may due to the fact that in general women seem to be less innovative compared to men, in terms of holding less patents (Milli et al., 2016). In fact, our results show that the probability of patenting decreases with the number of female founders. Previous research has explored some of the challenges that women face in participating in the patenting process, such as

women's underrepresentation in more patent-intensive STEM fields, and social biases which distort the perceptions of the formal IP systems.

On the other hand, in the service sector, however, where there are many more women-owned businesses, new business practices or new marketing practices are more common than conventional product or process innovations and these innovative practices are not detectable with patents or other forms of formal or informal IP (Robb and Coleman, 2014).

A second important result is that education and *not experience* of the founding team members is related to the probability of using IPPMs, especially formal IPPMs such as trademarks, and among high-tech manufacturing firms. This result goes in the same direction of Toivanen and Väänänen (2016) study of the causal effect of education on the propensity to patent. In their paper, they empirically support the common belief of the existence of a strong (causal) link between education and growth via innovation.

Firm characteristics such as R&D intensity, size and international engagement are found to be relevant for the choice of IPPMs. R&D intensive, larger and internationally oriented firms have a higher probability of using IPPMs to protect their innovations. The higher the R&D intensity, however, the higher the probability of choosing informal IPPMs, such as confidentiality agreements or design complexity. This result contrasts previous studies that look at the choice between patenting and secrecy for protection of innovation, and generally find that R&D-intensive firms are more likely to opt for patents (Hall et al., 2012), but corroborates previous findings that formal IPPMs like patents are not the most widely used mechanism to protect ideas and innovations (Cohen et al., 2000; Arundel, 2001), especially among small firms.

Moreover, in line with the findings of Leiponen and Byma (2009), we find that cooperation influences the choice of intellectual property strategy for SMEs, especially among service firms. In fact, services firms have long relied on collaboration for innovation (Arundel et al., 2007, Chesbrough, 2011), especially KIBS firms. As previously mentioned, due to the intangibility of services, innovations and appropriability conditions may differ between service and manufacturing activities, as service firms more often have the goal of organizational innovation rather than product innovation, and rely more on employees' skills and external cooperation rather than formal R&D (Tether, 2005; Montresor and Vezzani, 2016).

Finally, a market dominated by price competition discourages firms from adopting formal IPPMs or using trade secrets, while it increases the probability of using lead time advantage. Having some time advantage over competitors may enable a company to obtain better agreements with suppliers or to purchase strategic scarce assets that will allow the firms to keep costs (and prices) down. However, it must be mentioned again that the associations between IP choices and firm and market characteristics are based on the personal interpretation and perception of the respondents regarding the nature of the market structures, and the inability of the surveyor to verify the veridicality of firms' use of informal IP systems such as design complexity or lead time advantages.

To the extent that future research builds on our findings, care should be made at the time that data are collected to assemble weights that will allow one to measure the intensity of use of alternative IPPMs. For example, one might make an effort to learn, say on an annual basis, how frequently are the various IPPMs used; the IP protection budget for each firm and how that budget is allocated across the use of IPPMs; the cost to activate alternative IPPMs relative to their effectiveness; and the effectiveness of rival's IPPMs and innovation. And, the next step to understand the economic implications of using alternative IPPMs is to explore their use on the growth of innovative behavior and financial performance relative to a counterfactual situation wherein no IPPM was used.

Figure 1

Percentage of Firms Using Alternative IP Protection Mechanisms

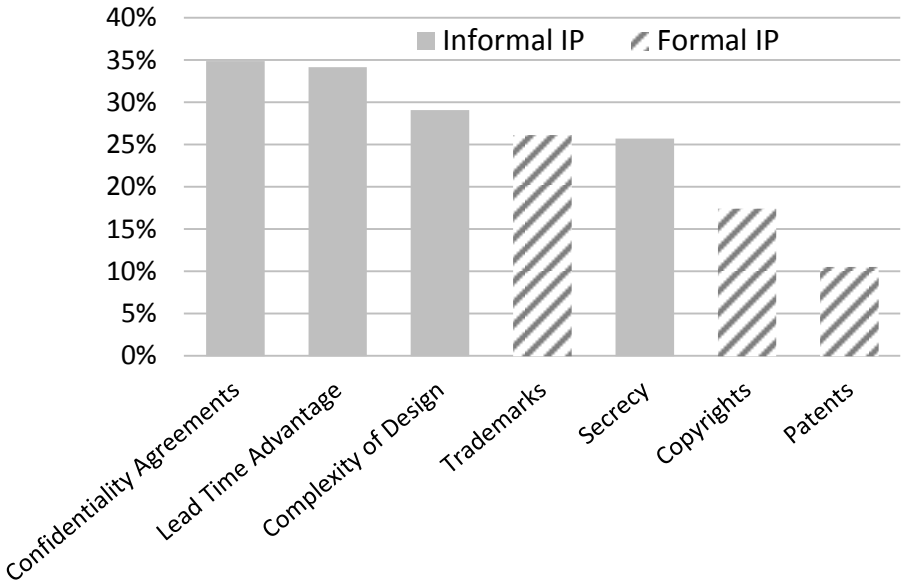

Figure 2

Percentage of Firms by Number of IP Protection Mechanisms Used

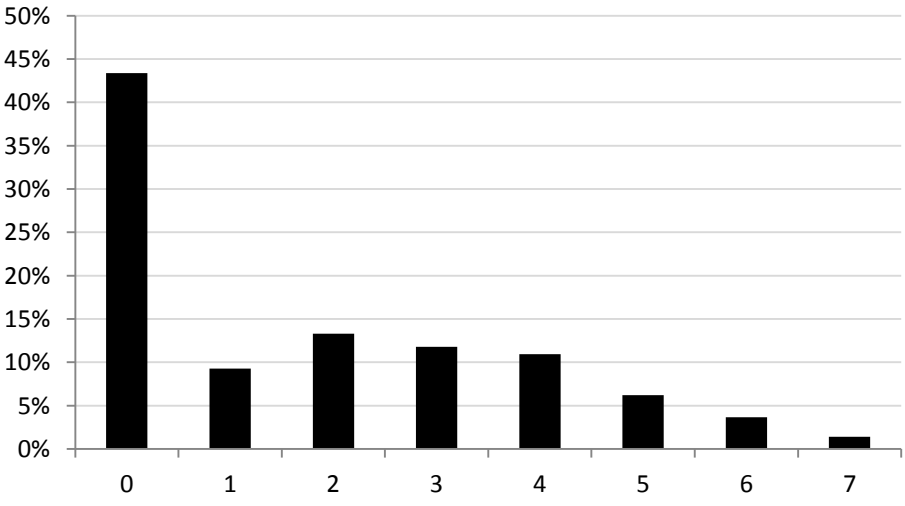

Table 1

Percentage of Firms Using Alternative IP Protection Mechanisms, by sector group

	All firms (n=4004)	High-tech (n=420)	Low-tech (n=1602)	KIBS (n=1982)
Formal IP	34.8%	39.0%	34.3%	34.2%
Patents	10.5%	20.7%	9.6%	9.2%
TMs	26.1%	30.5%	27.5%	24.2%
Copyrights	17.5%	11.7%	16.3%	19.6%
Informal IP	52.3%	61.9%	47.8%	53.9%
Confidentiality Agreements	34.9%	39.0%	24.7%	42.3%
Secrecy	25.7%	33.1%	19.5%	29.2%
Lead Time	34.2%	45.0%	33.3%	32.6%
Complexity	29.1%	43.3%	25.9%	28.7%
at least one IPPM	56.6%	64.5%	54.8%	56.4%

Note: The high-tech manufacturing sector includes aerospace; computers and office machinery; radio-television communication equipment; manufacture of medical, precision and optional instruments; pharmaceuticals; manufacturer of electrical machinery and apparatus, manufacturer of machinery and equipment, chemical industry. The low-tech manufacturing sector includes paper and printing; textile and clothing; food, beverage and tobacco; wood and furniture; basic metals; fabricated metal products. Knowledge-Intensive Business Services (KIBS) includes telecommunications; computer and related activities; research and experimental development; selected business services activities.

Table 2

Percentage (Number) of Firms Using Formal and Informal IPPMs

		Informal IP	
		no	yes
Formal IP	no	43.4% (1737)	21.9% (875)
	yes	4.3% (173)	30.4% (1219)

Table 3

Percentage (Number) of Firms Using at least one IPPM and Innovating

		at least one IPPM	
		no	yes
innovation	no	36.4% (1456)	0% (0)
	yes	7.0% (281)	56.6% (2267)

Table 4

Definition of Variables

Variable	Definition
IPPMs	
Formal	=1 if the firm has used at least one formal IPPM (patents, trademarks or copyrights)
Informal	=1 if the firm has used at least one informal IPPM (confidentiality agreements, secrecy, lead-time advantages on competitors, complexity of design)
Both IP	=1 if the firm has used at least one formal and one informal IPPM
Founding team characteristics	
Women	Number of female founders
International	Number of founders born outside the country of the firm
Experience	Sum across all founders of years of professional experience in the sector
Education	=1 if the average founder has at least a bachelor's degree
Team size	Number of founders (maximum of 4)
Control variables (firm and market characteristics)	
Size	Size of the firm measured as the log number of full-time employees plus two time the number of part-time employees
R&D intensity	Average percent of sales spent on R&D during the last three years
Radical innovation	=1 if the firm introduced a product or service during the last three years that is new to the market; 0 otherwise
Share if international sales	Percentage of sales during the last three years in the international market
Risk	=1 if the firm rates technology and market risks as important obstacles to the firm growth (larger than 3 on a scale from 1 to 5); 0 otherwise
Dynamic environment	=1 if the firm rates as important the following characteristic of its business environment: short life cycle of products, constant demand for new products, high speed of technological change, key role of innovation for survival (important=larger than 3 on a scale from 1 to 5); 0 otherwise
Cooperation	=1 if the firm rates as important for competitive advantage the establishment of alliances with other firms(important=larger than 3 on a scale from 1 to 5); 0 otherwise
Competition	=1 if the firm rates its business environment as prevalently characterized by price competition (important=larger than 3 on a scale from 1 to 5); 0 otherwise

Table 5

Descriptive Statistics of Control Variables

	Entire sample				Only Formal IP	Only Informal IP	Both IP	No IP
Variable	Mean	Std Dev	Min	Max	Mean	Mean	Mean	Mean
Founding team characteristics								
Women	0.37	0.62	0	4	0.42	0.34	0.33	0.40
International	0.17	0.50	0	4	0.16	0.16	0.21	0.14
Education	0.68	0.47	0	1	0.66	0.67	0.75	0.64
Experience	23.71	22.15	0	150	23.79	25.20	23.85	22.87
Team size	2.01	1.05	0	4	1.95	2.11	2.09	1.91
Control variables (firm and market characteristics)								
Size	1.69	1.17	0.69	7.25	1.85	1.80	1.92	1.46
R&D intensity	12.46	19.36	0	100	9.00	13.39	20.07	7.00
Radical innovation	0.04	0.19	0	1	0.06	0.06	0.07	0.00
Share international sales	14.45	26.49	0	100	10.54	14.70	20.32	10.59
Risk	0.47	0.50	0	1	0.47	0.49	0.50	0.43
Dynamic environment	0.74	0.44	0	1	0.64	0.75	0.83	0.68
Cooperation	0.37	0.48	0	1	0.27	0.37	0.47	0.30
Competition	0.52	0.50	0	1	0.35	0.58	0.46	0.54

Table 6

Probit with Sample Selection Correction[12]

Marginal effects of variables on the probability of using at least one IPPM by sample group

	All firms	high-tech	low-tech	KIBS
Women	-0.012*	0.005	-0.003	-0.019**
	(0.006)	(0.018)	(0.012)	(0.008)
International	-0.009	0.011	-0.021	-0.007
	(0.007)	(0.018)	(0.013)	(0.010)
Team size	0.002	-0.005	-0.005	0.008
	(0.005)	(0.012)	(0.009)	(0.006)
Education	0.018*	0.057*	0.020	0.004
	(0.009)	(0.033)	(0.015)	(0.013)
Experience	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
share international sales	0.001***	0.000	0.001**	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)
Size	0.011***	-0.004	0.011	0.010**
	(0.004)	(0.008)	(0.007)	(0.005)
R&D	0.058***	0.071**	0.055***	0.054***
	(0.010)	(0.035)	(0.017)	(0.013)
Risk	0.013*	0.011	0.006	0.017*
	(0.008)	(0.019)	(0.014)	(0.009)
Dynamic environment	0.007	0.013	0.009	0.000
	(0.009)	(0.024)	(0.018)	(0.011)
Competition	-0.001	0.01	-0.012	0.006
	(0.008)	(0.018)	(0.014)	(0.009)
Cooperation	0.015**	0.005	0.009	0.020**
	(0.008)	(0.018)	(0.015)	(0.009)
Country and sector fixed effects	yes	yes	yes	yes
N. observations (uncensored)	2,493	294	977	1221
Wald-test	1761.46***	76.74***	84.22***	100.66***
Pseudo R^2	0.127	0.112	0.281	0.140

Notes: *** significant at .01- level, ** significant at .05-level, * significant at .10-level

[12] First stage estimations are not reported, but available upon request.

Table 7

Bivariate Probit with Sample Selection Correction

Marginal Effects by IPPM

	P(Formal=1)	P(Informal=1)	P(Formal=1 AND Informal=1)
Women	-0.006	-0.028**	-0.018
	(0.019)	(0.012)	(0.018)
International	0.03	-0.018	0.018
	(0.021)	(0.013)	(0.020)
Team size	-0.014	0.015*	-0.005
	(0.013)	(0.009)	(0.012)
Education	0.075***	0.022	0.074***
	(0.025)	(0.017)	(0.024)
Experience	0.000	0.000	-0.001
	(0.001)	(0.000)	(0.001)
share international sales	0.001**	0.001**	0.001**
	(0.000)	(0.000)	(0.000)
Size	0.036***	0.025***	0.042***
	(0.010)	(0.007)	(0.010)
R&D	0.088***	0.079***	0.107***
	(0.029)	(0.022)	(0.027)
Risk	0.013	0.024*	0.021
	(0.021)	(0.014)	(0.020)
Dynamic environment	0.068***	0.048***	0.078***
	(0.026)	(0.018)	(0.024)
Competition	-0.088***	0.031**	-0.063***
	(0.022)	(0.014)	(0.021)
Cooperation	0.080***	0.038***	0.086***
	(0.022)	(0.014)	(0.021)
Country and sector fixed effects	yes		
N. observations (uncensored)	2,493		
rho	0.266*** (0.042)		
Wald-test	725.01***		

Notes: *** significant at .01- level, ** significant at .05-level, * significant at .10-level

Table 8

Multivariate Probit with Sample Selection Correction - Marginal Effects by IPPM

	Patents	TMs	Copyrights	Secrecy	Lead Time	Complexity	Confidentiality Agreements
Women	-0.037***	0.003	0.009	-0.028	-0.029	-0.006	-0.019
	(0.013)	(0.018)	(0.015)	(0.018)	(0.018)	(0.018)	(0.019)
International	0.028**	0.045**	0.024	-0.003	-0.003	-0.022	0.040*
	(0.013)	(0.021)	(0.016)	(0.021)	(0.022)	(0.021)	(0.024)
Team size	-0.017**	-0.016	-0.004	-0.004	0.01	0.013	0.022
	(0.009)	(0.013)	(0.011)	(0.013)	(0.013)	(0.013)	(0.014)
Education	0.019	0.076***	0.043**	0.080***	-0.061**	0.034	0.086***
	(0.016)	(0.024)	(0.020)	(0.024)	(0.024)	(0.024)	(0.025)
Experience	0.000	-0.001	0.000	0.000	-0.001	0.000	0.001
	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
share international sales	0.001***	0.001***	0.001***	0.002***	0.001**	0.002***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Size	0.015**	0.061***	-0.004	0.025**	0.013	0.029***	0.062***
	(0.006)	(0.010)	(0.008)	(0.010)	(0.010)	(0.010)	(0.010)
R&D	0.082***	0.130***	0.059***	0.132***	0.150***	0.165***	0.164***
	(0.015)	(0.024)	(0.020)	(0.023)	(0.025)	(0.024)	(0.026)
Risk	0.004	-0.023	0.015	0.066***	0.044**	0.032	0.046**
	(0.014)	(0.021)	(0.018)	(0.021)	(0.021)	(0.021)	(0.022)
Dynamic environment	0.023	0.026	0.057***	0.052**	0.082***	0.121***	0.034
	(0.017)	(0.025)	(0.020)	(0.025)	(0.026)	(0.025)	(0.027)
Competition	-0.049***	-0.106***	-0.039**	-0.061***	0.041*	-0.033	-0.008
	(0.014)	(0.021)	(0.018)	(0.021)	(0.022)	(0.021)	(0.022)
Cooperation	0.040***	0.088***	0.017	0.044**	0.033	0.042*	0.098***
	(0.015)	(0.022)	(0.018)	(0.021)	(0.022)	(0.022)	(0.022)
Country and sector fixed effects	yes						
N. observations (uncensored)	2,493						
Wald-test	1755.14***						

Notes: *** significant at .01- level, ** significant at .05-level, * significant at .10-level

Table 9

Estimated correlations between IPPMs

Matrix of $\widehat{\rho}$	*patents*	*TMs*	*copyrights*	*secrecy*	*lead time*	*complexity*
TMs	0.403***					
copyrights	0.267***	0.461***				
secrecy	0.120***	0.072**	0.190***			
lead time	0.089**	0.054*	0.123***	0.286***		
complexity	0.230***	0.126***	0.154***	0.310***	0.379***	
Confidentiality agreements	0.186***	0.101***	0.265***	0.642***	0.243***	0.206***

Notes: *** significant at .01- level, ** significant at .05-level, * significant at .10-level

Likelihood ratio test of $\rho_{21}=\rho_{31}=\rho_{41}=\rho_{51}=\cdots=\rho_{76}=0$: $\chi^2(21)=1049.09$ Prob > $\chi^2=0.0000$

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