Intellectual property protection mechanisms and the characteristics of founding teams

By: Sara Amoroso and Albert N. Link

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Abstract:

Intellectual property protection mechanisms (IPPMs) are critical to fostering science, technology, and innovation, and their relevance has grown enormously with the increased trade in goods and services involving patentable technologies. Scholars have investigated factors that facilitate or hinder the use of such IP protection strategies by identifying related country, sector, and firm characteristics. However, the extant literature has overlooked the role of the characteristics of a firm's founding team on the choice of an IPPM strategy. Using data from a large cross-sectional sample of European small, young, and innovative firms, we show that controlling for firm size, R&D intensity, and other firm and market effects, founding team characteristics, such as gender and education, greatly influence the choice of a strategy. In particular, in line with the general finding that women patent less, we find that firms with more women in the founding team patent less than firms with more male founders; but contrary to the literature that has primarily focused on large firms, we find that as the number of female founders increases, small, young entrepreneurial firms tend to use less informal IPPMs rather than formal IPPMs. We also find, within the context of entrepreneurship policy, that the education and *not experience* of founding team members is a main predictor of IP adoption.

Keywords: intellectual property | patents | appropriability | entrepreneurship | knowledge intensive firms | gender | founding teams | AEGIS survey

Article:

Introduction

One way for a firm to appropriate returns to its investments in research and development (R&D) and to protect the intellectual property (IP) it produces is to adopt various intellectual property protection mechanisms (IPPMs). It is widely accepted that intellectual property is an important asset for economic growth, and policymakers have long considered the use of IPPMs an effective way to protect as well as to stimulate innovative behavior (Gould & Gruben, 1997; Bloom & Van Reenen, 2002; Kwan & Lai, 2003; Helmers & Rogers, 2010, 2011; and Kim et al., 2012). In addition, IPPMs, such as patents, can play an important role in business success, especially

among young, innovative firms. In fact, holding a patent may help young ventures access private equity financing from venture capitalists (Graham et al., 2009; Haeussler et al., 2012). IPPMs have also been linked to greater market value among established businesses (Hall et al., 2005). To understand factors that play a role in the decision of selecting and using IPPMs, we look at both firms' characteristics and those of their founders. Indeed, we applaud the view of the World Intellectual Property Organization (WIPO, 2014, Chapter 2) that the fundamental driver behind any innovation process is the related human factor.

The literature on the choice of IPPMs revolves around three main empirical findings. First, the choice of one or more IPPMs 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 (Hall et al., 2013; Lanjouw & Schankerman, 2004; Veugelers & Schneider, 2017). However, large R&D firms, in the semiconductor industry for example, 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 & 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 among different IPPMs (Gallié & Legros, 2012; Landry et al., 2009) reflecting the fact that firms might rely on several protection mechanisms to protect different components of their increasingly complex and integrated innovations. The third recurrent empirical finding is that firms consider informal mechanisms to be more effective than formal ones to protect their innovations (Arundel, 2001; Cohen et al., 2000; Levin et al., 1987). In particular, when firms need to protect large valuable investments, they tend to resort to informal IPPMs, such as trade secrets or first mover advantage (Anton & Yao, 2004), in an effort of staving off free riders (Hall et al., 2014).

While the literature on the choice of IPPMs principally looks at traditional firm and sectoral characteristics,[1] previous studies have not investigated the link between the choice of IPPMs and the characteristics of the founding team. Founding teams are comprised of individuals with heterogeneous characteristics (e.g., age, gender, educational background, nationality, work experience) that could provide insight into the diversity of uses of IPPMs. This might be the case especially among young, innovative firms in which the strategic activities, and hence performance, are a direct reflection of the founders' characteristics and abilities. In fact, existing studies on the 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 who have prior experience in R&D are more likely to be innovative (Arvanitis & Stucki, 2012).

While other studies have looked at the heterogeneity of firm-level characteristics to disentangle IP strategy adoptions, to the best of our knowledge no other studies have looked at the

[1] 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.

heterogeneity of founding teams. When looking at young, innovative firms the role of human capital in the founding teams is extremely relevant from a policy perspective to promote skill formation, and to support entrepreneurship and their initial IP choices (Ehrlich et al., 2017).

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 an IPPM strategy. Indeed, controlling for country, sector, and firm characteristics, we investigate the compositional role of founding teams—in terms of age, gender, educational background, nationality, work experience—in the adoption of different IP strategies using information from a large sample of European small and young, innovative firms.

The remainder of this paper is outlined as follows. In "Background literature" section, we review the existing literature related to the choice of IPPMs. In "Data description and variables selection" section, we overview the AEGIS database and define the IPPM variables of interest of this paper. In "Empirical analysis" section, we discuss the variables used in our empirical estimation and we present our empirical findings. The paper concludes in "Discussion and conclusions" section with a summary of our findings and with our suggestions for future research.

Background literature

There are two faces to a patent. On the one hand, a patent provides an inventor monopoly privilege over an invention for a defined period of time, thereby providing an incentive to invest in R&D. On the other hand, a patent provides full disclosure of technical information about the invention, thereby dampening the impact of monopoly privilege 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 (Comanor & Scherer, 1969; Link & Scott, 2018; Schmookler, 1966). 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 (Arundel, 2001; Cohen et al., 2000; Levin et al., 1987). Gradually, the literature has shifted its focus from emphasizing patents to focusing on other IPPMs as well as to the benefits of 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 considered to include patents, trademarks and copyrights, while informal IPPMs include lead time, confidentiality agreements, design complexity, and trade secrecy.[2]

Firms that choose formal IPPMs are typically large, product innovators, R&D intensive, and they have less financial constraints (Hall et al., 2013; Lanjouw & Schankerman, 2004). The choice of informal IPPMs depends on firms' competitive strategy, when, for example, they need to protect

[2] 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.

large, valuable innovations (Anton & 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 firms. Using data from the EUROSTAT Community 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 focus mainly on firm and sector characteristics without considering the explanatory potential of founding teams' characteristics. These latter 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.

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 IPPM choices of young, innovative firms are the characteristics of its founders.

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.

The characteristics of founding teams have been at the core of several strands of literatures, although they have not been an area of focus in the IPPM literature. The management literature has studied the relationship between founding team diversity and firm performance without reaching a consensus (Nielsen, 2010; Stahl et al., 2010; Williams & O'Reilly, 1998). On the one hand, firms with diverse teams in terms of age, gender, and ethnicity are likely to perform worse because of internal conflict; on the other hand, diversity in education, professional background, and experience are conducive to greater innovate performance (Watson et al., 1993; Protogerou et al., 2017). Also, more diverse teams have higher levels of performance as they have access to a broader array of skills; however, more homogeneous teams tend to have faster execution and implementation (Beckman, 2006; Eisenhardt & Schoonhoven, 1990).

Eesley et al. (2014) suggest that the more educationally and professionally diverse the founding teams, 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. 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.

Human capital theory predicts that individuals with higher levels of human capital are generally more successful (Becker, 1964; Schultz, 1959), and that having a high level of human capital is helpful for acquiring other resources such as financial and social capital (Brush et al., 2001). Within this framework, empirical studies have looked at the intersection between founding team characteristics and innovation. Small and young firms typically rely on founders' characteristics as a strategic asset stress. Indeed, founders' capabilities are "critical resources to the creation of competitive advantage and early growth" (Protogerou et al., 2017, p.1313). Arvanitis and Stucki (2012) find that for Swiss startups, founders' characteristics of education, prior experience in R&D, and strong motivation to innovate have a positive effect on the probability of commercialize innovative activities. Using the AEGIS database (discussed below), Protogerou et al. (2017) find that founders' human capital, education and experience, is positively related to the R&D intensity and product innovation.

Empirical studies highlight an under-representation of women in innovative activities and in high-tech sectors across all countries (Alsos et al., 2013; Amoroso & Link, 2018); however, to date, research is only starting to discuss gender influences on the innovativeness of persons or firms (e.g., Nählinder et al., 2015). Not only there are fewer women start-up businesses than men, but also women-owned firms innovate less. This is related to the fact that women generally choose to operate in industries, such as retail and services, which are typically less patent intensive.

Boden and Nucci (2000), Robb (2008), and Fairlie and Robb (2009) find, using U.S. data, that women-owned firms have lower firm survival rates than men-owned firms. If survival rates are correlated with sales, and if sales are correlated with IP related outputs, then one might extrapolate and conclude that women-owned firms will be less IP active. The Bort et al. (2017) analysis of German startups from 10 different sectors shows that gender diversity decreases product innovations. In contrast, Andersen et al. (2017) find that small, women-owned firms, that receive public support for their research, are less likely to fail in their research compared to men-owned firms. This latter finding might suggest that women-owned firms are more likely to develop technology from their funded research, but the authors do not expand their analysis to consider IP from such technology (Link & Morrison, 2019). Cook and Kongcharoen (2010) rely on U.S. data to show that women are less likely to patent than men. Demilralp et al. (2018) go further with U.S. data to show that men-owned businesses in STEM (Science, Technology, Engineering, and Mathematics) fields are less likely to generate IP (including patents, trademarks, and copyrights) than women-owned firm.

Data description and variables selection

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).[3]

The AEGIS database contains information on 4,004 firms established between 2002 and 2007 across 10 European countries.[4] 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.[5] 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).[6] The sample of potential companies was drawn primarily from the population of firms found in the Amadeus (Bureau van Dijk) database. The sample form Amadeus was then integrated with data from Kompass and D&B. The resulting target population of knowledge-intensive entrepreneurial ventures and the final sample of surveyed firms are reported in Table 1.

Table 1. AEGIS survey population and sample, by country

Country	Target population	Survey sample	Coverage (%)
Croatia	2,747	200	7.28
Czech Republic	3,965	200	5.04
Denmark	10,191	330	3.24
France	128,163	570	0.44

[3] "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).

[4] A complete description of the AEGIS database is in Caloghirou et al. (2014). See also, https://cordis.europa.eu/project/id/225134/reporting. Additional information on the AEGIS database is available from the authors. The data used in this paper were graciously provided though Caloghirou.

[5] 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. (2014) and Link and Swann (2016) on this issue.

[6] 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.

Country	Target population	Survey sample	Coverage (%)
Germany	54,823	557	1.02
Greece	4,527	331	7.31
Italy	81,892	580	0.71
Portugal	16,412	331	2.02
Sweden	34,021	334	0.98
UK	24,055	571	2.37
Total	360,796	4,004	1.11

The target population includes all firms that are young, small, and knowledge-intensive in selected sectors (see Caloghirou et al., 2011 for the selection criteria) from 3 different data sources: Amadeus (Bureau van Dijk), Kompass, and D&B

As Caloghirou et al., (2014, p.15) state in their final report summarizing the methods and results from the AEGIS survey, the final sample of firms should.

> […] identify new entrepreneurial ventures that have been created recently in the decade and investigate their creation—growth—evolution. We do not want to count or map all the entities that have been created during these years in the examined countries. We do not want to make any quantified projections or draw conclusion on the representation of firms in Europe, as this is not the aim of this survey.

IPPM choices

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

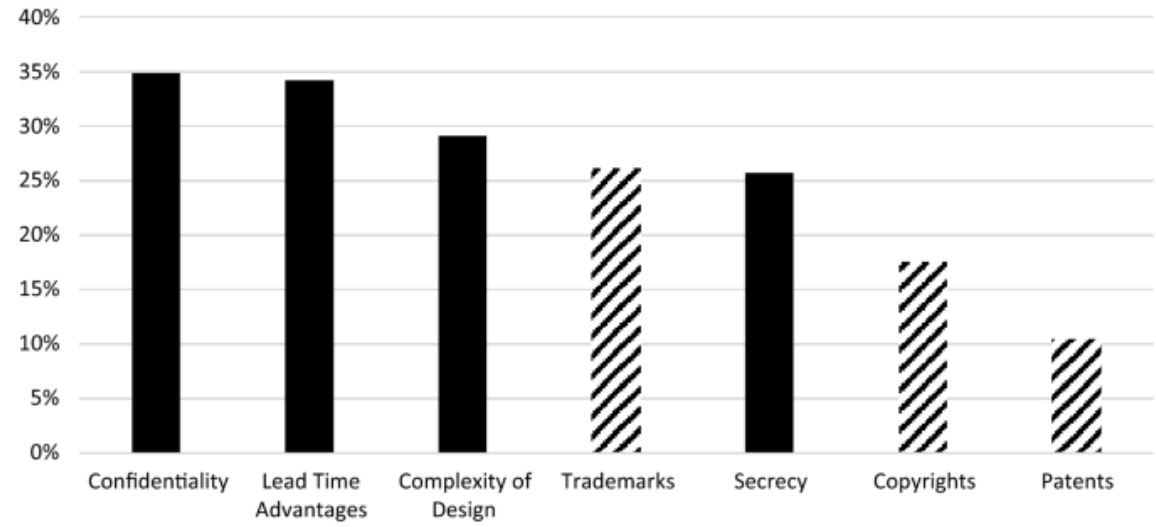
Please indicate [Yes or No] which of the following methods were used by your firm to protect its intellectual property during the last 3 years.

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 & 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.[7,8] In general, a larger proportion of firms choose informal IPPMs, such as

[7] 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.
[8] Confidentiality agreements (or non-disclosing agreements, NDA) are legal contracts between parties that outline confidential information that the parties wish to share with one another, excluding access to the information by third parties. Trade secrets, or secrecy, are practices or business methods that are generally unknown outside the company. Lead time advantage refers to the advantage that the first mover enjoys int the marketplace. Finally,

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 percent of the sample does not use any IPPM, while the remainder 57 percent of firms uses largely 1–4 IPPMs at the same time.



Formal IPPMs – hashed bars
Informal IPPMs – solid bars

Fig. 1. Percentage of Firms Using Alternative IP Protection Mechanisms

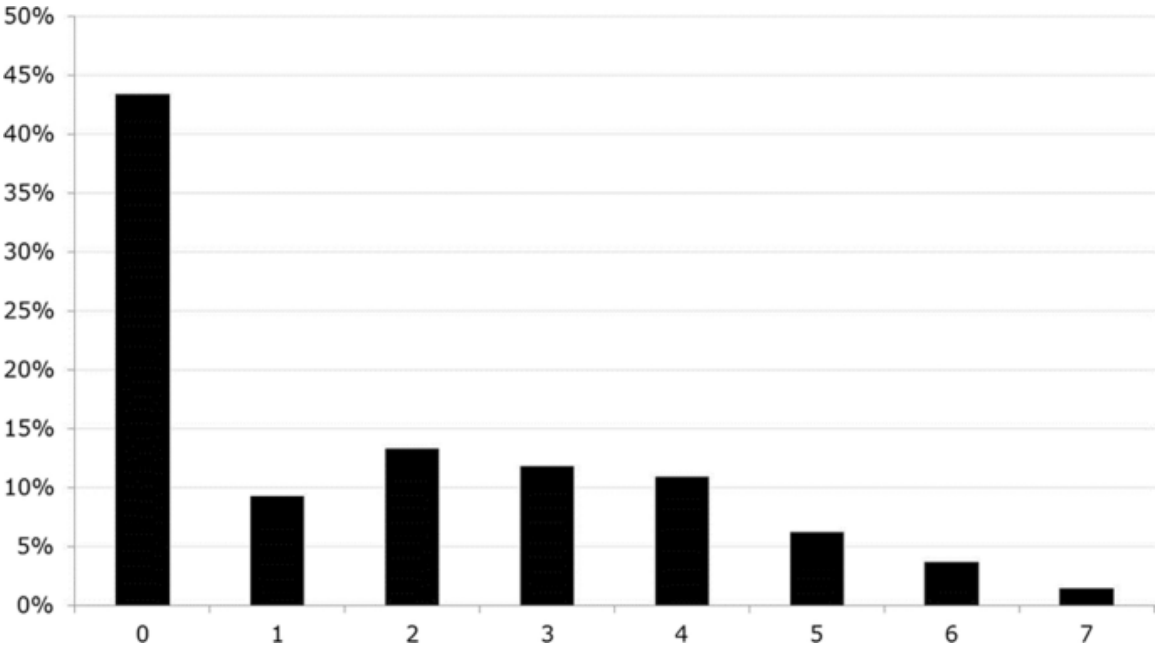


Fig. 2. Percentage of firms by number of IP protection mechanisms used

complexity of design, typically used for telecommunications and consumer electronics product, is the use of complex manufacturing techniques that sets products apart from lower-quality imitations.

The uses of the various IPPMs by formal and informal IPPM categories and sector group are reported in Table 2. 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 firms in other sectors. Among the informal IPPMs, confidentiality agreements are the most often used, especially by KIBS firms.

Table 2. Percentage of Firms Using Formal versus Informal Intellectual Property 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%
Trademarks	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%

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 3 reports the cross-tabulations for the two binary variables, formal and informal IPPM, that are equal to 1 if a firm has at least one formal or at least one informal IPPM, respectively, and 0 otherwise. As already shown in Fig. 2, 43 percent of firms do not use any IPPM, in great part because they do not have any innovative product or service to protect. Indeed, 36 percent of the firms in the sample do not have a new product or service (see Table 4). Only 7 percent of firms have a new product or service but decide not to use any IPPM.

Table 3. 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 4. 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)

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 & Sena, 2017; Hall et al., 2014; Levin et al., 1987).[9]

Founding team characteristics

As measure of founders' human capital, we use educational attainment (*Education*) and professional experience (*Experience*). Altogether, 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 (Klotz, 2014). Also, educational attainment may be positively related to the use of formal IPPMs, as Toivanen and Väänänen (2016) find a positive effect of university education on the propensity to patent.

To examine the link between gender of the founders and the IP choice, we control for the number of female founders (*Women*). 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.

Finally, we control for the nationality (*International*) and the number of founders (*Team size*, normalizing factor for the number of female and international founders). Heterogeneity 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, while entrepreneurial team size is positively related to new venture performance (Jin et al., 2017).

Firm characteristics

In line with previous studies, we consider a wide range of firm-level characteristics (Brower and Kleinknecht, 1999; Lanjouw & Schankerman, 2004; Hall et al., 2013; Veugelers & 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 have any a priori assumption on the relationship between the exports' share and the portfolios of IPPMs.

Finally, Eesley et al. (2014) suggest that 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 test the hypothesis of Eesley et al. (2014), we include a variable for the degree of cooperation among firms (*Cooperation*). Veer et al. (2016) also show that formal IP regimes

[9] It is important to point out 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.

work well at as mechanisms moderating the relationship between R&D cooperation and imitation, while informal IPPMs do not.

Market characteristics

As for market characteristics, we include the presence of obstacles, such as technology or market risk (*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. 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, according to the EUIPO (2012, p.9):

> price competition is typical of commodity-type markets, where opportunities for product differentiation/innovation are scant, and margins may be enhanced with cost/process innovation.

In summary, the choice among 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.

All the variables considered in our analysis are defined in Table 5, and the corresponding descriptive statistics are in Table 6, by category of IPPM (entire sample, only formal, only informal, both, or no IPPMs).

Table 5. 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)	

Variable	Definition
Size	Size of the firm measured as the log number of full-time employees plus two times 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 of 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

* Note: In the absence of any other information, we assume that 2 part-time employees are equivalent to 1 full-time employee. The estimated coefficients on firm size are virtually unchanged if log base 10 is used rather than the natural log. These results are available on request from the authors

Table 6. Descriptive statistics of control variables

Variable	Entire sample				Only Formal IP	Only Informal IP	Both IP	No IP
	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
	23.71	22.15	0	150	23.79	25.20	23.85	22.87
Team size	2.01	1.05	1	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

The left part of Table 6 reports means, standard deviations, and the ranges of values of all our variables for the entire sample. The right part of Table 6 shows only the means by type of IPPM. Some stylized findings are evident from Table 6. Firms that rely on both formal and informal IPPMs (under the column *Both IP*) have a significantly[10] 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,

[10] The results of *t*-tests with unequal sample size are not reported in Table 5, but they are discussed in the paper.

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.

Empirical analysis

In our sample, there are no firms that use at least one IPPM and have no innovation (Table 4), 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 (incidental truncation). 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:

$$\begin{aligned} S^* &= z'\theta + \mu, \\ S &= 1(S^* > 0), \\ Y^* &= \begin{cases} 0 & \text{if } S = 0 \\ \alpha + \boldsymbol{\chi}_i'\beta + \text{control}_i'\gamma + \varepsilon_i, & \text{if } S = 1 \end{cases} \\ Y &= 1(Y^* > 0), \end{aligned}$$

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 *x* includes the founding team characteristics discussed in Sect. 3.3, while *control* is the vector of firm and market characteristics; we also control for country and 2-digit sector dummies.

The vector *z* includes the founding team characteristics and control variables, plus the instrument variable *market power*.[11] While the economic rationale for IP rights rests on the ideas that a patent or any other IPPM would give firms a temporary monopoly rent, this has no empirical support, and a patent holder has no market power in any relevant sense if there are close substitutes for the patented product or service.

Table 7 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 services firms.[12] Similarly to Leiponen and Byma (2009), we report differences between manufacturing and services firms, as previous literature has shown that services firms' strategies of appropriation may differ from

[11] The indicator of market power is based on the survey question related to the number of competitors "Right now, are there other businesses offering the same products and/or services to your potential customers?" Answers: Yes, many; only a few; no other competitors. Given that these companies are all SMEs, it is plausible to assume that if the market is populated by many competitors, they do not have the same power to determine the market price as for example Apple Inc. in the smartphone market.

[12] All the tables with estimation results report the computed marginal effects, which are to be interpreted as follows: for continuous variables an increase by 1% (or 1 unit or 10% in case of logged variables) in x corresponds to a β (multiplied by a 100 in case of unit change or change in logs) percentage points change in probability of choosing an IPPM; for dummy variables the marginal effect tells us that category 1 corresponds to a $\beta*100$ change in probability of choosing an IPPM. For example, the coefficient of -0.012 for the variable "women" means that an additional woman in the founding team decrease the probability of choosing an IP strategy by 1.2 percentage points.

those of manufacturing ones, because of the intangibility of services (Boden & Miles, 2000; Tether, 2005). Moreover, in our earlier work, we show how female-founded firms tend to cluster in low-tech sectors (Amoroso & Link, 2018). The regression results suggest that some of the characteristics of the founding team matter for the choice of IPPM.

Table 7. Probit with sample selection correction marginal effects of variables on the probability of using at least one IPPM by sample group

	All firms	**High-tech**	**Low-tech**	**KIBS**
Women	−0.014*	−0.009	−0.001	−0.018**
	(0.008)	(0.019)	(0.016)	(0.007)
International	−0.011	0.015	−0.030*	−0.008
	(0.008)	(0.023)	(0.018)	(0.009)
Team size	0.001	−0.005	−0.009	0.007
	(0.006)	(0.012)	(0.012)	(0.006)
Education	0.020*	0.082*	0.029	0.000
	(0.012)	(0.043)	(0.021)	(0.012)
Experience	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Share international sales	0.001***	0.001	0.001**	0.000*
	(0.000)	(0.000)	(0.001)	(0.000)
Size	0.008*	0.005	0.012	0.005
	(0.005)	(0.009)	(0.011)	(0.005)
R&D	0.056***	0.336*	0.071*	0.043***
	(0.019)	(0.176)	(0.041)	(0.012)
Risk	0.014	0.022	0.008	0.014
	(0.009)	(0.022)	(0.019)	(0.009)
Dynamic environment	0.000	0.028	0.007	−0.008
	(0.011)	(0.032)	(0.026)	(0.010)
Competition	0.004	0.007	−0.008	0.011
	(0.009)	(0.019)	(0.020)	(0.009)
Cooperation	0.010	0.015	0.004	0.013
	(0.008)	(0.018)	(0.015)	(0.009)
Country and sector fixed effects	yes	yes	yes	yes
N. observations (uncensored)	2493	294	977	1221
Wald−test	245.44***	67.08***	40.59***	78.95***
LL	−3067.08	−57.51	−1261.5	−1495.70

***Significant at 0.01- level, **significant at 0.05-level, *significant at 0.10-level
First stage estimations are not reported, but available upon request

The 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, and the number of international founders is negatively related to the probability of having an IPPM among low-tech manufacturing firms.

The control variables partially confirm the findings of other studies. Being a large, R&D intensive, internationally engaged firm is positively associated with the probability of using IPPMs.

Table 8 shows the results for the marginal (unconditional) probabilities of using formal, informal or both types of IPPMs. The characteristics that have a statistically significant association with the choice of IPPMs are the number of women and foreign founders, the size the founding team, and the education of the team members. The numbers of women and foreign founders are negative related only to the probability of using informal IPPMs, while education is positively associated to formal IP or both types of IPPMs.

Table 8. Bivariate probit with sample selection correction marginal effects by IPPM

	P(Formal = 1)	P(Informal = 1)	P(Formal = 1 AND Informal = 1)
Women	−0.002	−0.024**	−0.012
	(0.018)	(0.012)	(0.018)
International	0.008	−0.031**	−0.006
	(0.021)	(0.014)	(0.020)
Team size	−0.021*	0.008	−0.014
	(0.011)	(0.008)	(0.011)
Education	0.056**	0.002	0.049**
	(0.026)	(0.018)	(0.025)
Experience	−0.001	0.002	0.000
	(0.003)	(0.002)	(0.003)
Share international sales	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)
Size	0.008	−0.005	0.005
	(0.014)	(0.010)	(0.013)
R&D	0.032	−0.018	0.020
	(0.057)	(0.037)	(0.054)
Risk	0.008	0.006	0.010
	(0.022)	(0.015)	(0.021)
Dynamic environment	0.027	−0.009	0.020
	(0.033)	(0.022)	(0.031)
Competition	−0.063***	0.065***	−0.026
	(0.024)	(0.017)	(0.023)
Cooperation	0.044*	0.005	0.040
	(0.025)	(0.018)	(0.024)
Country and sector fixed effects	Yes		
N. observations (uncensored)	2491		
rho	0.260*** (0.042)		
Wald-test	549.04***		

***Significant at 0.01- level, **significant at 0..05-level, *significant at 0.10-level

The larger the firm's export shares, the higher the probability of using IPPMs, with no significant differences across IPPM types. Price competition is negatively related to the probability of using formal, 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 formal IPPMs.

Table 9. Multivariate probit with sample selection correction—marginal effects by IPPM

	Patents	TMs	Copyrights	Secrecy	Lead Time	Complexity	Confidentiality Agreements
Women	−0.017**	0.000	0.008	−0.023*	−0.026*	−0.003	−0.005
	(0.008)	(0.012)	(0.010)	(0.012)	(0.014)	(0.013)	(0.014)
International	0.003	0.013	0.005	−0.005	−0.009	−0.025*	−0.004
	(0.008)	(0.014)	(0.012)	(0.014)	(0.016)	(0.015)	(0.017)
Team size	−0.010**	−0.012*	−0.008	−0.012*	0.000	0.006	0.003
	(0.004)	(0.007)	(0.006)	(0.007)	(0.008)	(0.008)	(0.008)
Education	−0.001	0.027	0.015	0.031*	−0.036*	0.013	0.040**
	(0.011)	(0.017)	(0.014)	(0.017)	(0.020)	(0.019)	(0.020)
Experience	0.000	−0.001	−0.001	0.003*	0.000	0.001	0.003**
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Share international sales	0.001***	0.000	0.001**	0.001***	0.001*	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Size	−0.002	0.013	−0.006	−0.001	−0.002	−0.008	0.018**
	(0.005)	(0.009)	(0.007)	(0.009)	(0.010)	(0.010)	(0.008)
R&D	−0.008	−0.01	−0.008	−0.017	0.044	0.001	0.002
	(0.021)	(0.037)	(0.031)	(0.038)	(0.041)	(0.040)	(0.044)
Risk	0.001	−0.003	0.010	0.004	0.010	0.003	0.000
	(0.008)	(0.015)	(0.012)	(0.015)	(0.016)	(0.015)	(0.017)
Dynamic environment	−0.002	−0.013	0.01	0.016	0.025	0.039*	−0.011
	(0.013)	(0.022)	(0.017)	(0.021)	(0.024)	(0.022)	(0.025)
Competition	−0.010	−0.048***	−0.011	0.000	0.050***	0.005	0.014
	(0.009)	(0.016)	(0.013)	(0.016)	(0.018)	(0.017)	(0.019)
Cooperation	0.002	0.018**	0.001	0.021	0.021	0.003	0.047**
	(0.010)	(0.008)	(0.014)	(0.017)	(0.019)	(0.018)	(0.020)
Country and sector fixed effects	Yes						
N. observations (uncensored)	2493						
Wald-test	1791.94***						

***Significant at 0.01- level, **significant at 0.05-level, *significant at 0.10-level

Table 9 reports the estimated marginal effects of a multivariate probit with sample selection correction to investigate the differences across the determinants of individual IP choices.

Table 10. Estimated correlations between IPPM-specific equation error terms

Matrix of $\hat{\rho}$	Patents	Trademarks	Copyrights	Secrecy	Lead time	Complexity
Trademarks	0.380***					
Copyrights	0.271***	0.492***				
Secrecy	0.107***	0.053**	0.175***			
Lead time	0.098**	0.045*	0.143***	0.310***		
Complexity	0.205***	0.149***	0.154***	0.315***	0.365***	
Confidentiality agreements	0.155***	0.115***	0.250***	0.670***	0.253***	0.221***

***Significant at 0.01- level, **significant at 0.05-level, *significant at 0.10-level
Likelihood ratio test of $_{21}= _{31}= _{41}=_{51} =\cdots= _{76} = 0$: $^2(21) =1068.92$ Prob > $^2= 0.0000$

The results show that more women in the founding team correspond to a lower probability of patenting, using trade secrets or lead time advantages. The presence of international founders has a negative effect on the probability of using complexity of design. Education is associated with an increase in the probability of using secrecy or 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. Team size is negatively related to the choice of formal IPPMs such as patents and TMs, but also secrecy.

Among the firm and market characteristics, firm export intensity positively correlates with almost all forms of IP protection. A market characterized by price competition is associated with a decrease in the probability of choosing TMs and is positively related to the choice of first mover advantage. Cooperation with other firms has a positive impact on the probability of choosing confidentiality agreements. Table 10 reports the estimates of the correlation between the equation error terms.

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 small and young entrepreneurial firms, 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 validates a number of findings in the literature related to firm characteristics and IPPM strategies, and it provides new findings regarding founding team characteristics.

First, the probability of choosing any form of IP protection is negatively related to the number of women in the founding team, especially among service firms. On the one hand, this may due to the fact that in general women seem to patent less (Milli et al., 2016).[13] In fact, our results show

[13] There is a rich literature that shows that women do patent less than men. That literature was recently summarized by Link and Morrison (2019). In their literature review, they point out that the gender-patent literature has primarily focused patent searches for the first listed owner of the patent. The subsequent comparisons are between male and female scientists and make and female STEM employees. Most of the cross-sectional firm studies (e.g., Veugelers

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 services sector, where there are more women-owned businesses than in the high-tech manufacturing sector, 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 & 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 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.

Our third result concerns the number of foreign founders and their negative relation with the use of IPPMs among low-tech manufacturing firms, especially informal IPPMs. This result goes against our expectations, given that the heterogeneity in nationality has been linked to increased innovation and creativity (Hambrick et al., 1998), which in turn we expected to stimulate the adoption of IPPMs.

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. As for size, in our sample of relatively small firms, the larger ones are more likely to choose an IP strategy, especially confidentiality agreements. According to findings in the previous literature (Brouwer and Kleinknecht, 1999; Pajak, 2016; Veugelers & Schneider, 2017) size can have opposite effects. On the one hand, large firms patent more because they have fewer financial constraints than small firms; on the other hand, small firms patent more to build their reputation.

In line with the findings of Leiponen and Byma (2009), we find that cooperation influences the choice of intellectual property strategy for SMEs, especially in the use of TMs or confidentiality agreements. Despite 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 (Montresor & Vezzani, 2016; Tether, 2005), we do not find any evidence of differences across sectors.

Finally, a market dominated by price competition discourages firms from adopting formal IPPMs, while it increases the probability of using lead time advantage. Having some time advantage over competitors may enable a firm 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

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and Schneider, 2017) do not consider or do not have access to the gender of the firm owner much less to the gender of the founding team.

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.

Our study has its limitations, due in part to the lack of certain appropriate data. First, the AEGIS sample contains limited information only for young, innovative firms. Despite previous studies claim that for young and small firms the founders' capabilities are essential (due to resource constraints) and founders' initial IP decisions shape their business model and strategy (De Vries et al., 2017), we cannot present evidence on how the relationship between founders' characteristics and IPPMs choice differ between firms of different ages or sizes.

Second, the AEGIS survey design was not intended to have a representative coverage of all countries and sectors, therefore we are not able to link our results to framework conditions such as regulatory frameworks, market conditions, entrepreneurial culture, etc.

Third, the survey data offers only limited information on the founders' education (i.e. we do not know if the founders have a more technical/engineering or social/business sciences background). This additional information could help to shed light on the relationship between IP and STEM education. Also, there are many other factors that affect the choice of IPPMs such as timing, costs, imitation risks, and infringement costs for competitors, as well as knowledge management practices (i.e., whether firms rely on a closed learning style or if they base their technological learning on a more open model with exchanges across firms (Jensen and Webster, 2009)), that are not accounted for in this paper.

And fourth, we are unable within the AEGIS data to take into account the explicit cost of using one IPPM strategy over another, and we are unable to impose lags on the timing of the effectiveness of the use of one IPPM compared to another.[14] These are important issues which future researchers may be able to take into account through longitudinal case studies.

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. 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.

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[14] We thank an anonymous reviewer for urging us to emphasize this point.

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