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# Technological competition and patent strategy: Protecting innovation, preempting rivals and defending the freedom to operate

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ABSTRACT

Drawing on the resource-based view of the firm, we examine the effect of technological competition over a patent on the firm's choice of patenting strategy. We claim that technological competition makes the traditional strategy of protecting focal innovations from imitation less likely and increases the likelihood of a play strategy — i.e. using patents to avoid the risk of hold-up by other patent owners, or as a bargaining chip in litigation and cross-licensing. However, we claim also that technological competition over a target close to the firm's core technology should lead to use of a fence strategy i.e. to blocking the commercial endeavors of rivals and preempting substitute inventions. We find support for our hypotheses using data from a large-scale survey of European patent applications.

## 1. Introduction

Technological competition often results in situations where two or more firms in parallel develop technologies and products that are close substitutes (Talia, 2006; Pacheco-de-Almeida and Zemsky, 2012; James et al., 2013). Famous examples of such competition include when Alexander Graham Bell and Elisha Gray both filed a patent for the telephone on the same day (Bell won the patent) (Thompson and Kuhn, 2020), and the much more recent case when Moderna, CureVac, and BioNTech's raced to patent important aspects of their mRNA vaccines (it is not clear that any of the firms will win the patent) (Storz, 2022). Obviously, being exposed to fierce technological competition can have very strong negative implications for whether a firm will be able to capture value from its research and development (R&D) investments which would in turn affect the competitive advantage of the firm (Polidoro and Toh, 2011; Paik and Zhu, 2016).

The patent race literature (e.g., Fudenberg et al., 1983; Harris and Vickers, 1987; Green and Scotchmer, 1995; Denicolò, 2000; Hopenhayn and Squintani, 2016) shows that the patent system stimulates technological competition, and that it affects firms' incentive for performing R&D. In this literature, typically, models rely on the assumption that patent protection offers an incentive to invent by promising the right to exclude competitors from the rents accruing from exploitation of proprietary resources. However, the patent system produces two ex-ante incentives to participate in a patent race: the expected monopoly rents granted to the winner and the risk of exclusion from the product market for the losers (Kultti et al., 2006; Schneider, 2008; Lemley, 2012). As a result, firms patent not only to exclude rivals and appropriate the benefits of their inventions in the product market (i.e., a positive incentive), but also to safeguard themselves against the risk of being blocked by other patents (i.e., a negative incentive).

Accordingly, protecting an invention from imitation (traditional blocking) is neither the only, nor always the most important reason for patenting. Firms engage in various patenting strategies such as use of blocking patents as a bargaining chip in cross-licensing negotiations and IP litigation (block to play), or as a means to preempt rivals from patenting substitute inventions (block to fence) (Granstrand, 1999; Cohen et al., 2000; Cohen et al., 2002; Bhaskarabhatla and Hegde, 2014). However, the more precise conditions under which firms adopt these strategies when facing R&D competition are far from clear. Indeed, the question of the conditions under which firms adopt a certain patenting strategy when experiencing competition, is arguably a very important question as different patent strategies in the face of R&D competition imply different costs, risks and potential benefits that can ultimately

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affect the competitive advantage of the focal firm. We address this question in this paper.

Earlier studies show that the patent strategy (e.g., block to play and block to fence) varies with technological complexity (Grindley and Teece, 1997; Cohen et al., 2002; Reitzig, 2004; Ziedonis, 2004; Galasso, 2012) and have also documented an association between competition and the acquisition of patent rights (but not patent use) (e.g., von Graevenitz et al., 2013) and between competition and unused patents (Torrisi et al., 2016; Walsh et al., 2016). Our work departs from these latter studies because we are not interested in unused patents by themselves; instead, in line with Cohen et al. (2000, 2002), we compare the traditional patent strategy (i.e., patenting to prevent imitation of an invention used in the market) with other "strategic" uses of patents, including strategic non-use.

Other strands of research study the relationship between competition and enforcement of patent rights through litigation in specific industries (Polidoro and Toh, 2011; Rudy and Black, 2018), and analyze the firm's incentive to license or freely disclose its technology to dissuade potential entrants and incumbents from developing alternative technologies (Gallini, 1984; Kulatilaka and Lin, 2006; Pacheco-de-Almeida and Zemsky, 2012). While these studies focus on a specific patent enforcing mechanism (litigation) or a particular defensive approach, they do not consider the wider set of strategic options firms can rely upon when they face technological competition and they do not contemplate the circumstances under which firms should go for the traditional imitation blocking strategy, as opposed to other strategic choices.

We contribute to the literature on innovation and patent strategy by developing a theoretical framework that links technological competition to different types of patent strategies — traditional, play and fence. We build on the resource-based view of the firm (e.g., Wernerfelt, 1984; Dierickx and Cool, 1989; Barney, 1991; Lippman and Rumelt, 2003) and the literature on appropriability (Arrow, 1962; Teece, 1986; Levin et al., 1987; Cohen et al., 2002; Winter, 2006; Hurmelinna-Laukkanen and Yang, 2022). Our study extends prior research on the association between technological competition and patent use or strategic non-use (Torrisi et al., 2016; Walsh et al., 2016), by explaining why in the context of direct technological competition, the firm tends toward a play rather than a traditional strategy. If the firm experiences direct competition during the development of a technological resource (as reflected in a patent), the presence of competitors for the same asset reduces appropriability, i.e. the firm's effectiveness in extracting value from the patented invention in the product market (Teece, 1986). In these circumstances, a play strategy is more likely than a traditional strategy because the firm faces potential appropriability problems pertaining to rivalry in the product market. Even if a resource is protected by patents, competitors working in the same technology space often can invent around them (Clarkson and Toh, 2010). Moreover, a play strategy addresses the risk of exclusion from the market, which is especially high when the firm needs patented technological resources owned by competitors (Cohen et al., 2000; Cohen et al., 2002). In contrast, if the technology is core, the risk of value expropriation makes a fence strategy more likely. Core technologies represent the platform for a firm's future inventions and therefore preventing others from building inventions based on a firm's core technology inventions is crucially important to guarantee long-term appropriability and a sustainable competitive advantage (Laursen et al., 2017).

We use data on 7,083 European patent applications, collected through an inventor survey conducted between 2010 and 2011. Our unit of analysis is patent application. Our empirical analysis distinguishes three patent strategies which for analytical reasons we consider mutually exclusive: the traditional strategy; the play strategy; and the fence strategy. If the inventor claims that a patent was used to protect an invention in the product market, the patent is classified as the traditional strategy regardless of its possible other strategic purposes. If a patent was filed for cross-licensing (along with other reasons such as blocking and prevent infringement suits) and used in cross-licensing or not used, the patent is classified as the play strategy. Finally, a patent filed to block competitors and not used in the product market, licensed or cross-licensed is classified as fence strategy. We match the survey data with data from other sources, which yields a novel set of data on patent applicants across different technologies and industries. We find overall support for our hypotheses.

## 2. Theoretical background

### 2.1. Patent strategies

The resource-based view of the firm highlights that sustained competitive advantage can stem from ownership of valuable resources that are imperfectly substitutable and imitable (Wernerfelt, 1984; Barney, 1991; Peteraf, 1993). Technology codified in patents is an important resource which often has these characteristics (see e.g., Silverman, 1999; Markman et al., 2004). As described above, in our terminology, a traditional strategy refers to the use of a patent to protect an invention used in the product market from imitation. In this case, patents are used to protect inventions that are further developed to produce new products or new processes (Somaya, 2012). We focus on two additional types of patent strategy. First, a fence strategy which is aimed at creating a patent fence around other patented inventions used commercially to cover different technical solutions targeting a similar functional outcome (Cohen et al., 2000; Cohen et al., 2002). This implies exploitation of a patent application to preempt competition even if the patent is not used in the product market or in a licensing deal (Gilbert and Newbery, 1982; Schneider, 2008; Walsh et al., 2016). Thus, fence is a "proprietary" strategy different from a traditional strategy because it does not prevent copying a patent used in the product market but protects another patent from the threat of substitution. Moreover, the adoption of a fence strategy increases the transaction costs of licensing and therefore "the likelihood of licensing declines. Also, since the goal is exclusivity, these patents tend not to be used for cross-licensing negotiations" (Cohen et al., 2002: 1361). Second, a play strategy typically entails using the patent as an instrument to gain the freedom to operate (Blind et al., 2006; Somaya, 2012). Firms undertake a play strategy to increase their bargaining power in IP litigation and cross-licensing, to access technologies developed by other organizations, to prevent involuntary infringements and to reduce the risk of hold-up by other patent holders (e.g., Hall and Ziedonis, 2001; von Graevenitz et al., 2013).

Note that our theoretical framework does not contemplate an independent licensing strategy. The main reason for this choice is that licensing can be seen to be an alternative way to the traditional strategy to monetize a patent in the market for technology, not alternative strategic uses such as those as expressed in the play and fence strategies. To keep our main model tractable, we do not consider licensing as an independent option. However, in the robustness check section of this paper we describe the results of estimations that allow for licensing being a fourth independent option.

### 2.2. Technological competition, the severity of the threat, and patent strategy

We assume that the introduction and announcement of new products are central competitive actions, and that in making their strategic decisions firms account for the actions of rivals (Smith and Grimm, 1991; Young et al., 1996). In our context, a competitive action is the adoption of a patent strategy aimed at protecting the firm's competitive advantage in the product market (Lippman and Rumelt, 1982), or reinforcing its competitive advantage by reducing the risks of holdup and litigation (Grindley and Teece, 1997; Cohen et al., 2002). Technological competition is intrinsic to the patent system, and the widespread diffusion of patents increases the likelihood that two or more firms will seek simultaneously to obtain patent protection for similar inventions.[1] We compare patent use in situations where the firm perceives a concrete competitive threat from other firms working on the same invention, to the situation where the firm has not identified a specific rival, and therefore competition remains potential, remote and probably less threatening. In our proposed conceptualization, technology competition is viewed as potentially decreasing the value of a patentable technological resource since it implies that the given new resource has become more substitutable.[2] In other words, a perceived current competitor will command a similar resource. In the situation where a firm is facing technological competition, the firm will be less inclined to apply the traditional patent strategy but will rather favor either a play or a fence strategy. The result of the use of a patent strategy other than the traditional one, is that the technological resource will not directly underpin the firm's competitive advantage in the product market but will be deployed to support the firm's competitive advantage, one way or another.

Central to our paper is the idea that when firms face technological competition, they will chose a strategy other than the traditional one, but that under these conditions, the choice will differ according to the severity of the threat and that the severity in turn will depend on whether the technological threat is predominantly a concern for the firm's core technology. While the loss of (a degree of) appropriability in general is challenging to firms, the loss of (a degree of) appropriability of a core technology is more severe, as it may imply a loss of long-run competitive advantage.

## 3. Hypotheses

### 3.1. Technological competition and a play strategy

We have argued that the traditional patent strategy is less attractive in the presence of perceived technology competition. We posit also that the firm can retain some of its ability to generate rents and/or capture the greatest share of future inventions spawned by its existing inventions, through the adoption of either a play or a fence strategy. As a starting point, we contend that competition over a technology will lead to the adoption of a play rather than a fence strategy for two main reasons. The first is that the patent system especially under the first-to-file rule, encourages protection of early stage R&D outcomes that are a "long way from practical application" (Mazzoleni and Nelson, 1998: 281), and the perception of competitors for the same invention is likely to reinforce this effect. Head-to-head search and competition leads firms to engage in incremental search to keep abreast of competitors or limit rivalry (Lieberman and Asaba, 2006; Katila and Chen, 2008) in the pursuit of appropriability. In the case of patents induced by head-to-head competition, the limited inventive step may reduce the firm's incentives to bear the costs of marketing a patented invention, i.e., to pursue a traditional strategy. Nevertheless, early stage, incremental inventions can become bargaining chips in cross-licensing negotiations and IP litigation. This makes a play strategy suitable due to the risk of litigation and increases the firm's freedom to operate.[3] In addition, the lower level of innovativeness referred to above, should make the firm less concerned about spillover effects and expropriation as a result of the sharing of proprietary technology with other parties — such concerns otherwise would lead to a traditional or a fence strategy.

The second reason is that perception of technological competitors exacerbates the fear of exclusion from the market (Lemley, 2012), which leads to patent for pure defensive reasons (i.e., to avoid that a firm's technology is blocked by others) (Walsh et al., 2016). Competition also spurs the firm to speed the pace of innovation and anticipate rivals' innovations (Kessler and Chakrabarti, 1996) in the quest for strengthening appropriability. However, resource endowments constraints limit the firms' ability to accelerate development activities under circumstances characterized by intense competition (Kessler and Chakrabarti, 1996). Hence, a strategy of technology exchanges with other organizations (e.g., through cross-licensing) is valuable because it can increase the speed of innovation. Adoption of a play strategy allows the firm to benefit from technology trading (e.g., cash from cross-licensing, costless access to another firm's technology), freedom of operation and savings on litigation costs. While firms sometimes rely on R&D collaborations to develop the resources needed to accelerate innovation, external acquisition of technologies in the technology market probably allows faster acquisition of resources and entails less organizational commitment (Chesbrough, 2003; Laursen et al., 2010; Leone and Reichstein, 2012).

The use of own patents to access others' patented technology is a strategy adopted by large IT companies like Hewlett-Packard and Micron Technologies, and exemplified by IBM's patent strategy reported by Jack Kuehler, president of IBM between 1989 and 1993: "[T]o shorten our cycles, we need to have access to the inventions of the rest of the world. And this is why IBM's own patent portfolio is so important. This library of patents gains us access to the inventions of others" (Bhaskarabhatla and Hegde, 2014: 1754). The use of patents to gain the freedom to operate is also important in other sectors characterized by rapid technical change, like biotechnology. For example, in "September 2003, three pharmaceutical companies, Cambridge Antibody Technology, Micromet AG and Enzon Pharmaceuticals, announced that they had signed a non-exclusive cross-license agreement. In the agreement, all three parties obtained substantial 'freedom to operate' authorizing each other to use some of their respective patented technology. This enabled them to conduct research and develop a defined number of therapeutic and diagnostic antibody-based products." (WIPO, 2005).

In sum, the above discussion suggests that technological competition leads firms to adopt a play strategy because of the potential benefits from technology trade and freedom of operation, and the need to reduce time-to-market and manage the costs of R&D activity via multiple external sources of innovation. We capture these arguments in the following hypothesis:

**Hypothesis 1a**. Knowing that other firms are racing for the same patent is associated with a higher likelihood of using a patent to pursue a play strategy.

### 3.2. Technological competition and fence strategy

In contrast, a fence strategy reduces the firm's ability to access external sources of technology since this requires some level of reciprocity, and a willingness to accept some outgoing spillover effects. At the same time, while a fence strategy may help to preempt potential competition by blocking substitute patents (Gilbert and Newbery, 1982;

[1] Similar to simultaneous inventions resulting from technological competition, twin publications may result from the race for priority in the academic science. However, unlike patent races, where the winner takes all', two papers reporting on the same or very similar independent discoveries may both be published (Bikard and Marx, 2020).

[2] Substitution of the technological resource could occur through imitation but whether competitors get access to a similar technology through imitation or through a parallel R&D process (or a combination of the two) is not of critical importance for our analysis.

[3] Similarly, international business works find that firms focus their business in markets characterized by a weak IP system to mitigate the risks of patent litigation (Paik and Zhu, 2016).

Schneider, 2008), it entails higher opportunity costs than a play strategy. These costs are related to the substantial potential benefits that the firm forgoes by not using the patent as a bargaining chip in the market for patents, or in IP litigation. Accordingly, we hypothesize:

**Hypothesis 1b**. Knowing that other firms are racing for the same patent is associated with a lower likelihood of using a patent to pursue a fence strategy.

### 3.3. Competition in core technologies and fence strategy

While we contend that technological competition is associated with the adoption of a play strategy, we claim also that the relationship between technological competition and patenting strategy is moderated by the proximity of the patented technology to the focal firm's core technology. Our focus on core technology is based on the assumption that core technologies are more critical resources than the other technologies possessed by the focal firm (Song et al., 2003; Laursen et al., 2017). We base our claim on two arguments. First, core technologies are important in the context of appropriability because they represent the knowledge areas in which the focal firm is most experienced. The extent of a firm's prior experience in a particular knowledge domain strongly affects the firm's subsequent invention success in that domain. Given that a firm's technological specialization profiles across domains are often path dependent (Patel and Pavitt, 1997; Cantwell and Fai, 1999), the firm's production of future technological resources will be built on what it has learned in the past. In other words, the firm's ability to innovate in the future will to a large extent depend on the core technologies the firm possesses, and the core technologies are therefore critical to the firm's sustainable long run value creation ability.

Our second argument is that a core technology often underpins a number of goods in the product market (Granstrand et al., 1997). Besides protecting specific inventions, patent fences isolate the rents from co-specialized organizational assets that are required to produce and commercialize an invention (Teece, 1986). Thus, a core technology reflects the firm's strategic stakes in particular resources, i.e. firm-specific, not easily contractible assets, that are important to build strategic position and competitive advantage (Somaya, 2003, 2012). This implies that the firm is especially vulnerable if competition is related to a core technology.

Based on this logic, we suggest that if the firm is competing in a core technology some of the forces discussed above, such as the need to access external technologies, will have a weaker effect on patent strategy, while others, such as the risk of outgoing spillovers and the potential loss of appropriability to the advantage of competitors, will become crucially important. Overall, we argue that under these circumstances, firms should adopt a strategy implying strong action toward preempting substitute inventions that could compromise a firm's appropriability. More precisely, we claim that racing for a core technology patent makes the pursuit of a fence strategy more likely over the undertaking of a play strategy. This is in line with studies that stress the importance of a fence strategy as a means to preempt rivals' substitute patents (Cohen et al., 2000; Schneider, 2008). A prominent example of adoption of a fence strategy is Du Pont's patenting in the 1940s of over 200 substitutes for nylon to protect its core invention (Hounshell and Smith, 1988). In the 1970s, Du Pont also patented a substitute for its patented Cromalin color proofing process for photographic film. The substitute patent was never employed commercially by Du Pont but was used as a barrier against the commercialization of similar inventions by competitors (Turner, 1998). This suggests that a patented technology can be used to strengthen the effect of patent protection for a related and critical technological resource in the form of a core technology. Isolating mechanisms such as patent fences, enhance the long term value of the IP (Lippman and Rumelt, 2003; Ceccagnoli, 2009; Rudy and Black, 2018), and signal credible commitment to aggressive protection of key resources (Clarkson and Toh, 2010).

In constructing a fence around a core technology, the firm may prevent substitute patents while signaling its determination to protect its core technology in future patent litigation. Litigations are likely to occur when a core technology is at stake, as suggested by a lawsuit that IBM has recently filed against LzLabs, a Swiss company accused of reverse engineering an IBM's mainframe technology. A company statement claims that “IBM has made significant investment in research and development in this critical technology field and will aggressively defend its investments and resulting patents against those who violate them” (Allam, 2022). Indeed, the pursuit of a fence strategy can be seen as a way of strengthening the firm's effectiveness in preventing others from basing their inventions on the firm's inventions. These arguments suggest that a fence strategy will be the likely outcome when a firm faces technological competition if it poses a threat of substitution of the firm's core technology. In sum, we suggest:

**Hypothesis 2a**. The proximity to the firm's core technology moderates the association between competition and patent strategy, such that if the technology protected by the patent is close to the firm's core technology, knowing that other firms are pursuing the same patent is positively associated with the likelihood of adopting a fence strategy.

### 3.4. Competition in core technologies and play strategy

A play strategy involves reducing investment in deterring substitute inventions while tolerating a degree of imitation (Polidoro and Toh, 2011). As already argued above, this strategy has some benefits but given the inevitable outgoing spillovers is also risky and ultimately could result in the destruction of the basis for the firm's ability to create sustainable long run value. Indeed, firms may be unwilling to take this risk over critical resources that underpin firms appropriability such as core technologies. Accordingly, in the case of a core technology a play strategy is less likely than a fence strategy because of the potential for critical outgoing spillover effects in the scenario of a play strategy. We hypothesize that:

**Hypothesis 2b**. The proximity to the firm's core technology moderates the association between competition and patent strategy, such that if the technology protected by the patent is close to the firm's core technology, knowing that other firms are pursuing the same patent is negatively associated with the likelihood of pursuing a play strategy.

## 4. Data and methods

### 4.1. Sample

This study draws on a novel dataset obtained by linking different types of data. The primary source is the INNOS&T survey of inventors located in 20 European countries (Austria, Belgium, Switzerland, Czech Republic, Germany, Denmark, Spain, Finland, France, UK, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Sweden, and Slovenia), Israel, the United States and Japan. The survey population was based on patent applications filed at the European Patent Office (EPO), with priority dates between 2003 and 2005, and resulted in 23,044 responses (20 % response rate) (Torrisi et al., 2016). Since the INNOS&T survey was conducted between 2010 and 2011, some of the inventors' answers (e.g., those we rely upon to gauge the actual use of the patent) refer to a period spanning over the second decade of the 2000s. Accordingly, the time elapsed between the data collection and our analysis is not dissimilar from the time frame of recently published articles which exploit survey data to address related topics (e.g., Roach and Cohen, 2013; Walsh et al., 2016).

We restrict our analysis to patents whose applicant is a business organization. Due to the presence of missing values in some of the variables factored into the regression model, the final sample encompasses 7083 observations. We matched the survey data to information from various other sources. EPASYS and PATSTAT (Coffano and Tarasconi,

2014) provided data for the period 1978–2013 which allows us to measure patent characteristics (e.g., number of citations), applicants (e.g., patent stock) and technological domain (e.g., Herfindahl index of technological concentration). Compustat, Global Vantage, Amadeus, Orbis and LexisNexis databases were used to collect corporate level accounting and financial data.

### 4.2. Dependent variable

Our dependent variable relies on two questions in the INNOS&T survey. First, the importance of the reasons for patenting the invention rated on a Likert scale from 0 (not important) to 5 (very important). In line with previous studies (Cohen et al., 2002; Blind et al., 2006), we consider the following reasons: blocking patents, preventing imitation by inventing around, pure defense, prevention of infringements suits, licensing, and cross-licensing. We consider a patenting reason to be relevant if the inventor assigns a score greater than or equal to the median value of that reason in the sample. Second, we rely on patent use after application, distinguishing between internal and external use. The former concerns commercial exploitation in a product, a service, or a manufacturing process. The latter includes licensing agreements and cross-licensing agreements, patent sales and start-ups. By combining the responses for the reasons for patenting and use of the patent, we operationalize the three strategies under scrutiny in this study.

To operationalize the concept of traditional strategy we construct a dummy variable (*Traditional strategy*) that takes the value 1 for internal use of the patent for commercial purposes regardless of the motivations for patenting, and 0 otherwise (see Table 1). We measure the concept of a play strategy using the dummy variable (*Play strategy*) which takes the value 1 for the two categories of patents described below, and 0 otherwise. The first category comprises patents used in cross licensing and taken to block similar patents, prevent imitation, as a pure defense mechanism, or to prevent infringements suits. The second category comprises patents not used, but taken for the same reasons as those of the first category (see, Granstrand, 1999; Cohen et al., 2002; Galasso, 2012).

Finally, to operationalize fence strategy we construct a dummy variable (*Fence strategy*) that takes the value 1 for patent applications designed to block similar patents or prevent imitation by inventing around, where neither licensing nor cross-licensing are considered important reasons for patenting. The resulting patent is not applied in internal (new products or services) or external (licensing or cross-licensing) activities (see, Cohen et al., 2002; Reitzig, 2004; Blind et al., 2009). Our dependent variable is a categorical variable whose outcomes correspond to the three mutually exclusive patent strategies. The traditional strategy accounts for 63.5 % (4495 patents) of the sample, fence strategy for 10.1 % (717 patents) and play strategy 26.4 % (1871 patents).

To check whether our operationalization of patent strategy is consistent with the evidence in previous studies of "strategic patenting", we look at the distribution of patents by legal status (granted, pending, refused/revoked and withdrawn) for each strategy. We observe a higher percentage of grants among "traditional" uses (54.44 %) compared to "strategic uses" (48.05 % for fence and 46.01 % for play). In contrast, we find a higher percentage of withdrawn patents in the subsample of "strategic uses" (35.93 % for fence and 36.87 % for play) than among patents used to pursue the traditional strategy (27.44 %). These differences among patent strategies are statistically significant and confirm that "strategic patents" often are aimed at establishing prior art and preventing rivals from patenting similar invention rather than maintaining market exclusivity (Baker and Mezzetti, 2005; Guellec et al., 2012).

We find differences among the three patent strategies also in terms of opposition proceedings against granted patents. In particular, the percentages of oppositions among patents used within a traditional strategy is 4.36 %, almost twice that for other strategies (2.55 % for fence strategy; 1.85 % for play strategy). Earlier studies show that patent oppositions are associated to various indicators of patent value (Harhoff et al., 2003; Harhoff and Reitzig, 2004; Blind et al., 2009). Thus, our data are consistent with an expected lower average quality of "strategic patents" compared to "traditional patents" (Guellec et al., 2012).

**Table 1**
Definition of patent strategies.

| Type of strategy | Reasons for patenting | Use of the patent |
|---|---|---|
| Traditional strategy | | (In-house Commercial use) & (No other uses) |
| Fence strategy | (Blocking patents or Preventing imitation by inventing around) & No Licensing or cross-licensing | Unused |
| Play strategy | (Blocking patents or Preventing imitation by inventing around or Pure defense or Prevention of infringements suits) & Cross-licensing | Cross-Licensing & (No In-house Commercial use & No other uses) or Unused |

### 4.3. Independent variables

To measure competition, we exploit a survey question that asked inventors: "During the invention process, were you aware of one or of several other parties competing with you for the patent?" Inventors could select among three options: i) no other parties known; ii) yes, one other party; iii) yes, several other parties. About 40.5 % inventors in the sample indicated other parties competing for the patent; 79 % of these reported the existence of several competitors; 21 % reported one competitor. Based on this, we construct the dummy variable *Competition,* which equals 1 if either one or several other parties were competing for the focal patent and 0 otherwise.

Our competition measure relies on the perception of the inventor, who interprets and represents the firm's external technological landscape. This is in line with earlier studies which emphasize that inventors are "often the best informed actor regarding the science of the invention and, often its possible applications and potentially interested licensees" (Kenney and Patton, 2009: 1413). It is also consistent with previous studies which show that inventors often benefit from incentive systems tied to the potential economic exploitation of inventions (Harhoff and Hoisl, 2007). Second, we examined the job descriptions of a random sample of 50 INNOS&T survey participants working in different technological areas, and employed by firms operating in different countries and sectors. We collected information from their LinkedIn profiles; in 40 cases, we found that at the time of the invention the respondent occupied the position of chief technology officer, chief security officer, managing director, R&D project manager or was involved in IP management and technology commercialization.[4]

To measure the proximity to the firm's core technology, we used the patent's IPC 4-digit class (e.g., G06K: Recognition of data; Presentation of data; Record carriers; Handling Record carriers) and calculate the share of the applicant's patent stock in the same class. This continuous variable (*Core technology*) ranges between 0 and 1, with higher values indicating greater proximity of the focal patent to the applicant's core technological activity. In the case of patents with multiple IPC 4-digit classes, the main technological class is the most frequently reported IPC 4-digit class in the patent document. When two or more IPC 4-digit

[4] Typically, inventors were involved in activities such as market research or competition analysis, intellectual property analysis and review of competitor's patents, opening of new business units, elaboration of the firm's product portfolio strategy, due diligence for the assessment of novel market opportunities and future product direction. A detailed description of activities is available upon request from the authors.

classes have the same frequency (7 % of the cases in our dataset), the main class was assigned randomly. In choosing the 4-digit level of aggregation we follow the literature (e.g., Somaya, 2003; Ganco, 2013).

### 4.4. Control variables

We account for various potential sources of heterogeneity at patent, firm and technology level. We control for the share of backward X-type and Y-type citations (*Backward XY citations*) of the patented invention to control for overlapping claims with earlier cited patents which may increase the likelihood of litigation.[5] We control also for the number of forward citations received by the focal patent in the 5 years following the application (*Forward citations*) and for the number of distinct 4-digit IPC subclasses the invention is allocated to (*Patent Scope*) (Lerner, 1994). Moreover, we control for the radicalness of the patented technologies (*Technological radicalness*) which is measured by the number of different IPC 3-digit classes of patents cited by the patent, excluding the IPC class of the focal patent (Laursen et al., 2017).

We factor into the regression model a control for the difficulty of the invention problem as reflected in the extent to which "an invention's components have been previously recombined" (Fleming and Sorenson, 2004: 916). Following Fleming and Sorenson (2004), we call this variable *Coupling* and build it using all the 327 thousand patent applications filed at the EPO with a priority between 2003 and 2005. We retrieve the IPC classes assigned to the patents in this population and treat them as the underlying pieces of knowledge of the focal invention. We consider the finest level of aggregation of IPC classes which encompasses >90 thousand unique codes for patents in the reference population. Following Fleming and Sorenson (2004), we construct the variable *Coupling* in two stages. The higher the value of *Coupling,* the more difficult the recombination task posed by the underlying components of the invention.

The number of co-applicants (*Co-applicants*) is included to account for ex-ante inter-firm agreements that could affect patent use — e.g., they may reduce the need for ex-post cross-licensing deals. The number of inventors (*Inventors*) is included to control for the importance of the research project for the company (Sapsalis et al., 2006).

The presence of complementary assets should increase the likelihood of a traditional strategy. Accordingly, we factor into the model the variable *Complementary assets* which is based on a question in the INNOS&T survey which asks inventors to rate from 1 (completely disagree) to 5 (completely agree) their agreement with the following statement: "the applicant had the complementary resources required to translate the invention into an economically valuable output." We control for missing information on complementary assets with a dummy variable. We factor into the model several additional variables that capture the influence of firm-level characteristics (Hall and Ziedonis, 2001; Galasso, 2012). First, we use the applicant's total patent stock (*Patent stock*) before the priority date of the focal patent; patent stock is calculated using the perpetual inventory method with a depreciation rate of 15 % (Hall et al., 2005). Second, we use the value of the applicant's fixed assets in the year closest to the priority date of the patent (*Fixed assets*) as a measure of firm size; a dummy is included also to control for missing data on fixed assets.

Third, prior research points out that firms enjoying a technological edge are more concerned about the appropriability benefits offered by patents than technology laggards (Arora et al., 2016). Accordingly, we control for the effect of applicants' technological leadership on the choice of patent strategies.[6] To accomplish this task, we construct the *Leadership* variable which counts the number of technological fields, out of the 35 reported in the WIPO taxonomy (Schmoch, 2008), in which the focal firm is a technology leader. To classify firms as leaders or laggards in each technological field, we perform a *k-means* cluster analysis (Stata, 2021) based on three bibliometric characteristics of the patent (i.e., number of claims; family size; number of forward citations) which are commonly used for estimating the value of a patent portfolio (Harhoff et al., 2003; Hall et al., 2005; Teece, 2021). In constructing the variable *Leadership*, we consider all patent applications with a priority year between 2003 and 2005 (i.e., 203,855 patents) filed at the EPO by the applicants in the INNOS&T sample (i.e., 8056 applicants). Thereafter, the assessment of a firm's technological leadership in our analysis is not confined to observations in the working sample but reflects its overall patenting propensity during the period under scrutiny. We find that 67.47 % of firms in our working sample belong to the group of followers. 21.32 % of firms qualify as a leader in just one technology field and 11.21 % of firms qualify as a leader in two or more technology fields. We observe statistically significant differences between the average values of the three patent characteristics mentioned above across the two groups. The average number of claims is equal to 31.20 for leaders and 12.41 for laggards. The average value of family size is 5.96 for leaders and 5.22 for laggards. Finally, the average number of forward citations in the seven years after the filing of the patent application is equal to 1.06 for leaders and 0.86 for laggards. This piece of evidence indicates that the procedure opportunely discriminates between the two groups.

To control for technology-specific characteristics we include a variable reflecting the complexity of the patented technology, we use the complexity measure developed by von Graevenitz et al. (2013) which calculate the number of triples, i.e. the number of groups of three firms linked by reciprocal references (i.e. X-type and Y-type references to prior patents) for each technology class over the period 1988–2002. We use the median number of triples (*Complexity*) over this time span. Technology-level controls include also *Technological concentration* measured by the Herfindahl index calculated using data on patent applications filed at the EPO until 1998 by all the applicants operating in the IPC 4-digit technology area of the focal patent. We include also dummies for technology area and priority year. For the technology dummies, we use the OST-DT7 classification (OST, 2004). Finally, we control for country specificities regarding patent strategy by including Country dummies for Germany, France, Italy, Switzerland, United Kingdom, Other European countries, USA, Japan, and the Rest of the World. Germany, France, Italy, Switzerland, United Kingdom, USA, and Japan are the largest countries in terms of patent applications in the INNOS&T database (i.e., >700 patents per country).

### 4.5. Estimation

We employ a multinomial logit model to analyze the choice between the three patent strategies. We standardize the continuous independent variables by dividing them by twice the sample standard deviation and centering the dichotomous variables around the sample mean (i.e., demeaned). This scaling method allows comparison of the regression coefficients of the continuous and dichotomous covariates (Gelman, 2008). We performed estimation using also the original values of the variables; the sign and significance of the regression coefficients are unchanged. These results are available on request. To analyze the interaction terms, we adopt the method developed by Ai and Norton (2003). In unreported regressions, we applied the method proposed by Bowen (2012) which yielded very similar results to those presented below.

[5] Citations to prior art are coded "X" in the patent office search report if the invention cannot be considered novel or cannot be considered as involving an inventive step according to the work referenced. The code "Y" indicates that the invention does not involve an inventive step if the document referenced is combined with one or more other documents in the same category in a combination obvious to a person skilled in the pertinent art.

[6] We thank a reviewer for encouraging us to explore the differential effect that competition has on patenting strategies among technology leaders and laggards.

## 5. Results

Table 2 reports the descriptive statistics of the variables used in the empirical analysis. Multicollinearity is not a concern in our setting since most of the associations between key regressors are smaller than 0.15 in absolute values. We estimated a set of multinomial logit models and compare the traditional strategy (the reference category) to the fence strategy and the play strategy. Multinomial logit estimates imply the assumption of independence of irrelevant alternatives (IIA). The Hausman and McFadden (1984) cannot reject the IIA assumption which supports our estimation strategy. The results are available upon request from the authors.

Table 3 reports the average marginal effects (AMEs) of the standardized variables used in the multinomial logit estimations. The table shows the AMEs for three regression models: Model 1 includes only the control variables; Model 2 augments the regression equation by introducing *Competition* and *Core technology;* Model 3 introduces their interaction. All estimations are performed using sampling weights to correct for coverage and non-response bias. Standard errors are clustered at the level of the patent applicant to account for correlated errors. In what follows, we discuss the results under Model 3.

### 5.1. Main findings

Hypotheses 1a and 1b state that the perception of competitors racing to patent similar inventions is positively related to the probability of pursuing a play strategy and negatively related with the chance of adopting a fence strategy. In line with these hypotheses, we find that competing with other firms for the same patent (*Competition)* is associated with a 2.8 percentage points increase in the probability of adopting a play strategy and a 2 percentage points decrease in the probability of adopting a fence strategy.

Hypotheses 2a and 2b predict that firms' awareness of competitors racing for the same patent pertaining to a core technology, should be associated with a higher probability of adopting a fence strategy rather than a play strategy. Estimates concerning the direct effect of the variable *Core technology* and those referring to the interaction term *Competition*×*Core technology* lend support to this conjecture. The AME estimated for *Core technology* indicates that a two standard deviation increase in this variable is related with a decrease of 4.7 percentage points in the likelihood of pursuing a play strategy. The AME estimated for the interaction term *Competition*×*Core technology* hints to a surge of 3.3 percentage points in the probability of a fence strategy, which is in line with hypothesis 2a. Instead, there is no correlation between the interaction term and the probability of a play strategy, which does not support hypothesis 2b.

We further illustrate the influence of the interaction term by describing how the AME of *Competition* varies at representative values of *Core technology*. For a patent distant from the core technology (*Core technology* equal to 0.1), a change in *Competition* from 0 to 1 decreases the probability of a fence strategy by 4 percentage points (from 0.12 to 0.08). However, for a patent close to the core technology (*Core technology* equal to 0.9), a change in *Competition* from 0 to 1 increases the probability of a fence strategy by about 1 percentage point (from 0.09 to 0.10). Thus, the marginal effect of *Competition* on the probability of adopting a fence strategy changes from negative to positive as the patent gets closer to the core technology. This piece of evidence is consistent with Hypothesis 2a. Regarding the effect of competition on the probability of pursuing a play strategy, the marginal effect of *Competition*

**Table 2**
Descriptive statistics and correlation matrix.

| Variables | Mean | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Traditional strategy | 0.635 | 0.482 | | | | | | | | | | | | | | | | | |
| 2. Fence strategy | 0.101 | 0.302 | −0.44 | | | | | | | | | | | | | | | | |
| 3. Play strategy | 0.264 | 0.441 | −0.79 | −0.20 | | | | | | | | | | | | | | | |
| 4. Competition | 0.405 | 0.491 | −0.07 | −0.03 | 0.10 | | | | | | | | | | | | | | |
| 5. Core technology | 0.424 | 0.343 | 0.12 | 0.00 | −0.13 | −0.12 | | | | | | | | | | | | | |
| 6. Inventors | 2.568 | 1.823 | −0.05 | −0.02 | 0.07 | 0.08 | −0.09 | | | | | | | | | | | | |
| 7. Co-applicants | 0.096 | 0.46 | −0.04 | 0.01 | 0.03 | 0.05 | −0.01 | 0.17 | | | | | | | | | | | |
| 8. Backward XY citations | 0.276 | 0.343 | −0.04 | 0.01 | 0.04 | 0.01 | 0.00 | 0.01 | 0.00 | | | | | | | | | | |
| 9. Technological radicalness | 0.231 | 0.842 | 0.00 | −0.01 | 0.01 | 0.01 | −0.04 | −0.01 | 0.01 | −0.02 | | | | | | | | | |
| 10. Coupling | 0.754 | 0.624 | 0.04 | −0.02 | −0.04 | −0.03 | 0.08 | −0.03 | 0.00 | −0.03 | −0.04 | | | | | | | | |
| 11. Forward citations | 2.093 | 3.416 | −0.03 | −0.01 | 0.04 | 0.09 | 0.00 | 0.18 | 0.04 | −0.05 | −0.02 | 0.00 | | | | | | | |
| 12. Patent scope | 1.487 | 0.769 | −0.03 | 0.02 | 0.02 | 0.04 | −0.06 | 0.03 | 0.00 | 0.03 | 0.15 | −0.20 | 0.07 | | | | | | |
| 13. Complementary assets | 3.617 | 1.378 | 0.23 | −0.08 | −0.19 | −0.10 | 0.02 | 0.03 | −0.01 | −0.03 | −0.03 | 0.02 | 0.04 | −0.04 | | | | | |
| 14. Patent stock | 549.717 | 1425.941 | −0.09 | −0.03 | 0.13 | −0.01 | −0.34 | 0.07 | −0.02 | 0.02 | −0.01 | 0.00 | 0.02 | −0.02 | −0.01 | | | | |
| 15. Fixed assets | 9242.186 | 23,363.340 | −0.08 | −0.02 | 0.11 | 0.04 | −0.23 | 0.10 | 0.03 | −0.01 | 0.00 | −0.02 | 0.05 | 0.00 | −0.02 | 0.23 | | | |
| 16. Leadership | 1.296 | 1.887 | −0.07 | 0.03 | 0.05 | −0.03 | −0.14 | 0.09 | 0.02 | 0.00 | 0.01 | −0.02 | 0.11 | 0.04 | 0.05 | 0.10 | 0.04 | | |
| 17. Complexity | 18.972 | 29.286 | −0.06 | −0.06 | 0.11 | 0.04 | −0.10 | −0.01 | −0.03 | −0.04 | −0.01 | 0.04 | 0.00 | −0.06 | −0.07 | 0.16 | 0.04 | 0.07 | |
| 18. Technological concentration | 0.008 | 0.01 | −0.02 | −0.01 | 0.04 | 0.02 | −0.06 | 0.00 | −0.02 | −0.03 | −0.01 | 0.07 | 0.00 | −0.02 | 0.00 | 0.10 | 0.06 | 0.00 | 0.14 |

Note: Correlation coefficients above |0.03| are statistically significant at the 5 % level. $N = 7083$. Fixed assets are expressed in millions of Euros. Dummies for technology areas, countries, priority years and those identifying missing values in the variables Coupling and Fixed assets are not included for the sake of clarity.

**Table 3**
Multinomial logit estimates of patent strategies.

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| VARIABLES | Fence strategy | Play strategy | Fence strategy | Play strategy | Fence strategy | Play strategy |
| Competition | | | −0.019** | 0.028** | −0.020** | 0.028** |
| | | | (0.009) | (0.014) | (0.009) | (0.014) |
| Core technology | | | −0.017* | −0.046*** | −0.016* | −0.047*** |
| | | | (0.009) | (0.014) | (0.009) | (0.014) |
| Competition * Core technology | | | | | 0.033** | −0.014 |
| | | | | | (0.015) | (0.024) |
| Inventors | −0.019** | 0.008 | −0.020** | 0.008 | −0.020** | 0.008 |
| | (0.009) | (0.011) | (0.009) | (0.011) | (0.009) | (0.011) |
| Co-applicants | 0.007 | 0.012 | 0.007 | 0.012 | 0.006 | 0.012 |
| | (0.007) | (0.011) | (0.007) | (0.011) | (0.007) | (0.011) |
| Backward XY citations | −0.002 | 0.031*** | −0.002 | 0.030*** | −0.002 | 0.030*** |
| | (0.008) | (0.010) | (0.008) | (0.010) | (0.007) | (0.010) |
| Technological radicalness | −0.004 | 0.003 | −0.005 | 0.003 | −0.005 | 0.003 |
| | (0.008) | (0.011) | (0.008) | (0.011) | (0.008) | (0.011) |
| Coupling | −0.004 | −0.041*** | −0.003 | −0.039*** | −0.003 | −0.039*** |
| | (0.011) | (0.013) | (0.010) | (0.013) | (0.010) | (0.013) |
| Forward citations | −0.008 | 0.040* | −0.006 | 0.042* | −0.006 | 0.042** |
| | (0.007) | (0.021) | (0.007) | (0.021) | (0.007) | (0.021) |
| Patent scope | 0.009 | −0.015 | 0.008 | −0.016 | 0.008 | −0.016 |
| | (0.008) | (0.012) | (0.008) | (0.012) | (0.008) | (0.012) |
| Complementary assets | −0.048*** | −0.150*** | −0.049*** | −0.151*** | −0.049*** | −0.151*** |
| | (0.007) | (0.010) | (0.007) | (0.010) | (0.007) | (0.010) |
| Patent stock | −0.012 | 0.064*** | −0.017* | 0.052*** | −0.017* | 0.052*** |
| | (0.009) | (0.012) | (0.010) | (0.011) | (0.010) | (0.011) |
| Fixed assets | −0.015 | 0.030*** | −0.016 | 0.027*** | −0.016 | 0.027*** |
| | (0.012) | (0.009) | (0.012) | (0.009) | (0.012) | (0.009) |
| Leadership | 0.017** | 0.022* | 0.015* | 0.018 | 0.015* | 0.018 |
| | (0.008) | (0.013) | (0.008) | (0.013) | (0.008) | (0.013) |
| Complexity | 0.012 | 0.112** | 0.013 | 0.113** | 0.013 | 0.114** |
| | (0.045) | (0.045) | (0.045) | (0.046) | (0.045) | (0.046) |
| Technological concentration | −0.005 | 0.024** | −0.004 | 0.024** | −0.004 | 0.024** |
| | (0.009) | (0.012) | (0.009) | (0.012) | (0.009) | (0.012) |
| Technology dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Country dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 7083 | | 7083 | | 7083 | |
| Log Pseudolikelihood | −79,387.382 | | −79,163.047 | | −79,135.803 | |

Notes: Values in the table are Average Marginal Effects (AMEs). Robust standard errors clustered on patent applicant in parentheses. All models include dummies for missing values in the variables Coupling and Fixed assets.
***, **, * denote statistical significance at the 1 %, 5 %, and 10 % level, respectively, based on two-tailed tests.

slightly decreases as the patent gets closer to the core technology,[7] but it is not statistically significant on the two considered values of *Core technologies*. Thus, Hypothesis 2b is not supported by the data.

The marginal effects associated with a few control variables are worth mentioning. At the firm level, we find that an increase in the number of technology fields in which the focal firm occupies a leadership position is associated with a higher probability of adopting a fence strategy (0.015), rather than a traditional one (although at only the 10 % level of significance). Instead, no statistically significant correlation is detected with respect to the pursuit of a play strategy. These findings point out that technology leaders are more concerned about technological competition and try to preempt rivals by raising a wall around core assets. Moreover, the effect stemming from technological leadership is distinct from the effects linked to other firm's characteristics. For instance, our model predicts that firms with a higher resource commitment to downstream markets, proxied by the variable *Fixed assets*, are more inclined to pursue a play strategy (0.027) rather than a traditional strategy.

Additional insights come from the controls at the technology level. A two standard deviation increase in *Complexity* correlates with an 11.4 percentage points growth in the probability of a play strategy, whereas it is not related with the probability of a fence strategy. These results corroborate the idea that technological complexity spurs firms to engage in a play strategy (Cohen et al., 2002). Moreover, a two standard deviation increase in *Technological concentration* implies a raise of 2.4 percentage points in the likelihood of adopting a play strategy. Finally, a two standard deviation increase in *Coupling* is linked with a decline of 3.9 percentage points in play strategy, which highlights how the difficulty of technological recombination affects the viability of a play strategy.

### 5.2. Further analyses and robustness checks

To examine the robustness of our results and to shed additional light on our arguments and findings, we conducted additional analyses. The full results of these exercises are not reported here due to space constraints but are available upon request from the authors. The first exercise considers the fact that the variable *Competition* combines in, a single category, observations where the inventor claimed that only one competitor was racing for the focal patent and observations for which the inventor identified several competitors. Given that the effect of *Competition* might be driven by the number of competitors (a proxy for competition intensity), we estimated our models for two subsamples: patents with just one technological competitor and patents with more competitors. The results of these estimates, reported in Table 4,

[7] For a patent distant from the core technology (*Core technology* equal to 0.1), shifting *Competition* from 0 to 1 increases the probability of a play strategy by 4 % (from 0.27 to 0.31). On the other side, for a patent close to the core technology (*Core technology* equal to 0.9), shifting *Competition* from 0 to 1 increases the probability of a play strategy by 3 % (from 0.24 to 0.27).

**Table 4**
Multinomial logit estimates of patent strategies—by subsamples based on the number of competing firms for the same patent.

| Variable | Patents with more than one technological competitor | | | | Patents with only one technological competitor | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 4 | | Model 5 | | Model 6 | | Model 7 | |
| | Fence strategy | Play strategy | Fence strategy | Play strategy | Fence strategy | Play strategy | Fence strategy | Play strategy |
| Competition | −0.017 | 0.032** | −0.017 | 0.032** | −0.026** | 0.012 | −0.026** | 0.011 |
| | (0.010) | (0.016) | (0.010) | (0.016) | (0.013) | (0.019) | (0.013) | (0.020) |
| Core technology | −0.014 | −0.042*** | −0.013 | −0.042*** | −0.024** | −0.046*** | −0.024** | −0.046*** |
| | (0.009) | (0.014) | (0.009) | (0.014) | (0.011) | (0.015) | (0.011) | (0.015) |
| Competition × Core technology | | | 0.045*** | −0.001 | | | −0.008 | −0.046 |
| | | | (0.017) | (0.026) | | | (0.025) | (0.039) |
| Observations | 6841 | | 6841 | | 4814 | | 4814 | |
| Log Pseudolikelihood | −72,809.845 | | −72,760.031 | | −54,057.082 | | −54,043.116 | |

Notes: Values in the table are Average Marginal Effects (AMEs). Robust standard errors clustered on patent. All models comprise the set of control variables described in Table 3: they are not shown here for the sake of clarity.
***, **, * denote statistical significance at the 1 %, 5 %, and 10 % level, respectively, based on two-tailed tests.

highlight that the effect of competition on the firm's patent strategy is mainly driven by patents with more than one technological competitor. More precisely, the AMEs under Model 5 indicate that the focal firm is more likely to pursue a play strategy (0.032) whenever multiple rivals are racing for the same patent. However, such a choice only applies to patents outside the core technology. Focal firms facing multiple competitors for a core technology patent will be more inclined to endorse a fence strategy (0.045). Results under Model 7 point out that the focal firm is not going to adopt a preempting strategy when it perceives that only one rival is racing for the same patent. On the contrary, if the patent does not involve a core technology, the firm is less likely to pursue a fence strategy (−0.026) than a traditional one.

The second exercise investigates whether the relationship between technological competition and patent strategies differs between technological leaders and laggards. To carry out this analysis, we estimated our models for two subsamples: patents applied for by firms which qualify as leaders in at least one technology field, and patents applied for by firms which do not qualify as leaders in any field. The AMEs shown under Model 9, in Table 5, highlight that technology followers are more likely to adopt a play strategy when they are aware of competitors racing for the same patent (0.053). On the contrary, results under model 11 reveal that technology leaders are more likely to pursue a fence strategy when the threat posed by competitors involves assets closer to their core technology (0.065).

A joint interpretation of the empirical evidence emerging from the two exercises described above offers an interesting qualification of the main results discussed in the previous subsection. The perception of firms racing for the same patent does not necessarily lead the focal firm to adopt a fence strategy. In such a situation, a technology laggard would be inclined to pursue a play strategy even if the race for the focal patent involves several competitors. In contrasts, a technology leader would likely adopt a fence strategy when the patent race involves a technology closer to its core and when the threat comes from more than one competitor.

Our estimations could be subject to endogeneity problems. Specifically, the key regressors in our model, *Competition* and *Core technology*, might be endogenous, which would bias our estimations. First, the presence of competitors could be affected by the firm's patent use rather than vice versa. Moreover, the firm might decide to patent in less crowded technological fields to avoid competition. Second, *Core technology* is a choice variable which could be correlated to the motives for patenting and patent use. To assess if endogeneity could be biasing the results of the multinational models, we carried out an estimation exercise based on a two-stage residual inclusion (2SRI) approach (see, Terza et al., 2008). In the first stage, we use a probit and an ordinary least squares model to estimate the effect of selected instrumental variables and other exogenous covariates on competition and core technology, respectively.[8] In the second stage, we add the residuals of the first stage regressions in the multinomial logit estimates of patent strategies.

We instrument *Competition* with two variables: (i) a variable reporting the inventor age at the time of the invention (*Inventor age*); and (ii) a variable reflecting the importance of patent documents as source of information in the inventive process (*Patent documents as source*). Older inventors usually hold senior positions in R&D labs and enjoy a higher degree of strategic autonomy (Bailyn, 1985) which allows them to explore business opportunities outside the established chain of command (Burgelman, 1983). While exploring the technological landscape, inventors gather information about competitors working on the same technological trajectory, especially those racing for similar inventions. Inventors with more experience and those who enjoy higher autonomy are also more likely to interact with colleagues outside the R&D department (Giarratana et al., 2018). Accordingly, their knowledge of rivals competing for the same patent can be shared with managers responsible for the patent strategy and inform their decision making about the patent use. Thus, we believe that the variable *Inventor age* affects the awareness of technological competitors, while it is not alleged to have a direct impact on the patent strategy adopted with respect to the focal patent.

We use the variable *Patent documents as source* as an instrument for *Competition* as well. A question in the INNOS&T survey asks the inventor to report the importance of patent documents as sources of information during the inventive process (*Patent documents as source*), on a Likert scale from 0 (=not used) to 5 (=very important). We draw on this question to build six dummies used as instrumental variables. Access to patent documents reveal others' technological capabilities and research trajectories (Hsu and Ziedonis, 2013), which increases the awareness of technological competitors. At the same time, there are no compelling reasons to believe that reading patent documents influences the firm's strategic use of a specific patent.

To instrument *Core technology,* we use two variables. First, we use the country specialization in the technology of the focal patent, which is measured as the applicant's country share of EPO patents developed in the period 1990–2000 in the IPC 4-digit class. Studies on technological specialization of regions and countries (e.g., Jaffe et al., 1993; Nelson, 1993) suggest that firms are more likely to invent in technological fields in which the country is specialized.

For the core technology variable, we also include five dummy variables gauging applicant's age: 0–2 years (Age 0–2 years), 3–5 years (Age 3–5 years), 6–10 years (Age 6–10 years), 11–20 (Age 11–20 years) years and ≥21 years (Age ≥ 21 years) (the reference class). We expect the

[8] The results on the first stage estimates available upon request from the authors are in line with our expectations.

**Table 5**
Multinomial logit estimates of patent strategies—by subsamples based on the firm's technological position.

| Variable | Patents developed by technology laggards | | | | Patents developed by technology leaders | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 8 | | Model 9 | | Model 10 | | Model 11 | |
| | Fence strategy | Play strategy | Fence strategy | Play strategy | Fence strategy | Play strategy | Fence strategy | Play strategy |
| Competition | −0.015 | 0.053*** | −0.015 | 0.053*** | −0.019 | 0.009 | −0.021 | 0.011 |
| | (0.011) | (0.019) | (0.011) | (0.019) | (0.013) | (0.019) | (0.013) | (0.019) |
| Core technology | −0.033*** | −0.024 | −0.034*** | −0.022 | −0.005 | −0.042** | −0.004 | −0.044** |
| | (0.012) | (0.018) | (0.012) | (0.018) | (0.013) | (0.020) | (0.013) | (0.020) |
| Competition × Core technology | | | −0.005 | 0.025 | | | 0.065*** | −0.061 |
| | | | (0.020) | (0.029) | | | (0.023) | (0.038) |
| Observations | 3214 | | 3214 | | 3869 | | 3869 | |
| Log Pseudolikelihood | −30,543.438 | | −30,534.971 | | −47,635.375 | | −47,564.746 | |

Notes: Values in the table are Average Marginal Effects (AMEs). Robust standard errors clustered on patent. All models comprise the set of control variables described in Table 3: they are not shown here for the sake of clarity.
***, **, * denote statistical significance at the 1 %, 5 %, and 10 % level, respectively, based on two-tailed tests.

R&D activities of young firms to be relatively narrow and concentrated in a few technologies which will increase the likelihood of inventing close to a firm's core technology. Older firms accumulate excess resource capacity which can lead to the integration of a wider range of technological fields to benefit from economies of scope in R&D activities (Penrose, 1959). Moreover, established firms tend to diversify their technological portfolios to develop increasingly complex products and production processes, coordinate with other participants in the value system, and monitor externally generated technologies (Granstrand et al., 1997; Patel and Pavitt, 1997). Thus, older, technologically diversified firms are more likely to invent in fields that account for a limited share of their technological portfolio as compared to younger players. On the other hand, we have no reasons to expect that firm age is directly correlated to use of a single patent.

Table 6 shows the results of the 2SRI regression approach. At the bottom of the table, we report the Durbin-Wu-Hausman tests (Hausman, 1978) for the endogeneity of *Competition* and *Core technology*, the weak instrument *F*-test (the null hypothesis is that the coefficients of the instrumental variables are jointly equal to zero) and the Sargan-Hansen overidentification tests (Davidson and McKinnon, 1993) for the 2SRI estimates. Assuming that at least one of the instruments is valid, the results of these tests suggest that endogeneity might be a concern for *Competition* and *Core technology,* and they lend support to the value of our group of instruments in terms of their strength and validity. To further test the overidentifying restriction of the second-stage equation we adopted an approach similar to what Bollen et al. (1995) propose and the results are in line with the Sargan-Hansen overidentification tests.

The sign and statistical significance of the estimated AMEs from 2SRI multinomial logit estimates are very similar to those of the Standard Multinomial Logit: the only differences between the two methods regard the magnitude of the AMEs. These differences can be explained by the inclusion of the residuals of the first stage estimates as additional regressors in 2SRI models, which account for the potential endogeneity of our variables of interests.

We conducted additional robustness checks whose results are summarized below. As explained in the theoretical background section of this paper, due to the focus of our paper on the traditional patent strategy versus strategic applications of patents in terms of the play and fence strategies, in our conceptual and empirical models, we did not allow for licensing (beyond cross-licensing) to be an independent strategy in the face of technological competition. However, we also estimated multinomial logit models with licensing as an additional (fourth) separate and non-overlapping outcome. In these models, the variable licensing (not including cross-licensing) takes the value of 1 when the patent is used for licensing and has no other uses, and zero otherwise. The number of patents included in the pure licensing strategy is 86. The estimations including the licensing variable reveal that the association between licensing as an outcome and competitors racing to patent a similar invention (*Competition*) is not different from the estimations pertaining to the traditional patent strategy, nor is it significant in models where *Competition* is interacted with core technologies (*Core*). In addition, the parameters for the key independent variables relating to the play and fence strategies are literally unaffected by the inclusion of licensing as a fourth outcome in our models. The results of this robustness check are available upon request from the authors.

Given that we have firms in our sample with multiple patents, we also attempted to estimate a multinomial logit with firm fixed effects in the attempt to exploit within-firm variation to test shifts in patent strategies. However, the estimation of the log-likelihood function did not converge due to the characteristics of the subsample of observations, and the nature of the dependent variable used in our analysis. However, it is worth noting that when we estimated a model using random effects this model did converge. The results pertaining to this estimation are very similar to our main results (as documented in Table 3), except for the fence strategy which becomes significant at the 10 % level instead of the 5 % level.

To check whether the effect of *Competition* is influenced by technological complexity, in addition to controlling for *Complexity* we tested the interaction *Competition* × *Complexity* and found no significant effect on the play or fence strategy. To measure the patent's distance from the firm's core technology we rely on patent stocks. To control for possible biases in the evaluation of the impact of *Core technology*, we excluded firms with patent stocks in the lowest part of the distribution (5th percentile). The results are similar to those reported earlier.

## 6. Discussion and conclusions

Economists and strategy scholars have been adding to our knowledge about the strategic management of IP (Gilbert and Newbery, 1982; Granstrand, 1999; Cohen et al., 2002; Kultti et al., 2006). The literature recognizes that firms can use patents not just as legal instruments but also as competitive weapons (e.g., Grindley and Teece, 1997; Rivette and Kline, 2000; Hall and Ziedonis, 2001; Gambardella et al., 2007; Somaya, 2012; Bhaskarabhatla and Hegde, 2014). We contribute to this stream of research by having proposed a theoretical framework that explores the relationship between technological competition and a wide set of patent strategies, and explains how the proximity of a patented invention to the firm's core technology moderates this relationship. The theoretical framework predicts that if the firm is aware of other organizations competing for the same invention, it will be more likely to adopt a play strategy and less likely to adopt a fence strategy, rather than pursuing traditional commercialization. Our prediction was based on the consideration that developing in-house all the technologies required to respond to (or anticipate the actions of) rivals is costly, thus firms need to access external knowledge, possibly using their technology for exchanges in the market for technology. We found empirical support for these ideas.

**Table 6**
2SRI multinomial logit estimates of patent strategies.

| | Model 12 | | Model 13 | |
|---|---|---|---|---|
| VARIABLES | Fence strategy | Play strategy | Fence strategy | Play strategy |
| Competition | −0.072*** | 0.312*** | −0.072*** | 0.311*** |
| | (0.011) | (0.019) | (0.011) | (0.019) |
| Core technology | −0.114*** | −0.122*** | −0.112*** | −0.122*** |
| | (0.021) | (0.030) | (0.021) | (0.031) |
| Competition * Core technology | | | 0.132*** | −0.078*** |
| | | | (0.018) | (0.020) |
| Inventors | −0.022*** | 0.006 | −0.021*** | 0.006 |
| | (0.004) | (0.004) | (0.003) | (0.004) |
| Co-applicants | 0.007*** | 0.010** | 0.007*** | 0.010** |
| | (0.003) | (0.004) | (0.003) | (0.004) |
| Backward XY citations | −0.002 | 0.026*** | −0.001 | 0.026*** |
| | (0.003) | (0.004) | (0.003) | (0.004) |
| Technological radicalness | −0.007*** | 0.008* | −0.007*** | 0.008* |
| | (0.003) | (0.004) | (0.003) | (0.004) |
| Coupling | 0.003 | −0.038*** | 0.003 | −0.038*** |
| | (0.004) | (0.005) | (0.004) | (0.005) |
| Forward citations | 0.000 | 0.039*** | 0.000 | 0.039*** |
| | (0.004) | (0.013) | (0.004) | (0.013) |
| Patent scope | 0.006** | −0.019*** | 0.006** | −0.019*** |
| | (0.003) | (0.005) | (0.003) | (0.005) |
| Complementary assets | −0.051*** | −0.151*** | −0.051*** | −0.151*** |
| | (0.003) | (0.004) | (0.003) | (0.004) |
| Patent stock | −0.043*** | 0.030*** | −0.043*** | 0.030*** |
| | (0.007) | (0.009) | (0.007) | (0.009) |
| Fixed assets | −0.025*** | 0.024*** | −0.025*** | 0.024*** |
| | (0.005) | (0.005) | (0.005) | (0.005) |
| Leadership | 0.007** | 0.005 | 0.007* | 0.006 |
| | (0.003) | (0.005) | (0.003) | (0.005) |
| Complexity | 0.019 | 0.119*** | 0.018 | 0.119*** |
| | (0.016) | (0.019) | (0.016) | (0.019) |
| Technological concentration | −0.002 | 0.018*** | −0.001 | 0.018*** |
| | (0.003) | (0.004) | (0.003) | (0.004) |
| Residual (stage 1) - Competition | 0.064*** | −0.302*** | 0.063*** | −0.302*** |
| | (0.014) | (0.021) | (0.014) | (0.021) |
| Residual (stage 1) - Core | 0.100*** | 0.080** | 0.099*** | 0.080** |
| | (0.021) | (0.031) | (0.021) | (0.031) |
| Technology dummies | Yes | Yes | Yes | Yes |
| Country dummies | Yes | Yes | Yes | Yes |
| Year dummies | Yes | Yes | Yes | Yes |
| Endogeneity test (chi2-test) | 4.31 | 31.74*** | 6.45* | 31.64*** |
| Weak instrument test for Competition (F-test) | 388.99*** | | 388.99*** | |
| Weak instrument test for Core technology (F-test) | 28.68*** | | 28.68*** | |
| Over-identification test (F-test) | 1.09 | 1.35 | 1.06 | 1.33 |
| Observations | 7083 | | 7083 | |
| Log Pseudolikelihood | −78,853.207 | | −78,811.714 | |

Notes: Values in the table are Average Marginal Effects (AMEs). Robust standard errors clustered on patent applicant in parentheses; bootstrapped standard errors with 1000 replications for 2SRI estimates. All models include dummies for missing values in the variables Coupling and Fixed assets. The variable *Competition* is instrumented using two variables which gauge the age of the inventor and the importance of patent documents as source of information in the inventive process. The variable *Core technology* is instrumented using the index of technological specialization of the applicant's country and the age of the applicant.
***, **, * denote statistical significance at the 1 %, 5 %, and 10 % level, respectively, based on two-tailed tests.

We theorized also that competition in a core technology implies that the firm will prefer a fence strategy — which protects the private returns by limiting outgoing knowledge spillovers — over the traditional commercialization strategy, and that firms should prefer the traditional commercialization strategy over the play strategy under these circumstances. We contended that firms will be willing to incur the high opportunity costs of a fence strategy because it allows a strong protection of their core technologies against substitute technologies. We found empirical support for the choice of the fence strategy by the focal firm over the traditional strategy when the competing technology is core to the focal firm, but no support for the idea that that firms should prefer the traditional commercialization strategy over the play strategy in this situation.

Our findings have implications for the resource-based view of the firm. An early version of the resource-based view (known also as strategic factor market theory) posits that the cost of acquiring strategic resources will approximately equal the economic value of those resources unless buyers are consistently better informed about their future value, or just happen to be lucky (Barney, 1986: 1231–1232). Subsequent extensions (see for instance, Dierickx and Cool, 1989; Adegbesan, 2009; Grimpe and Hussinger, 2014) argued that the firm's existing resources can exhibit complementarities to resources not in its possession, implying that their combination will lead to higher economic rents than the sum of the value that these resources could yield on their own. This implies that firms should "build to buy" or "build to pick" resources in the strategic factor market to generate or sustain their competitive advantage (Makadok, 2001; Adegbesan, 2009).

Our analysis examined a situation that parallels the "build to buy" scenario. In our case, technological competition makes the traditional strategy of patenting a resource used in the product market less appropriate because rent appropriation in the product market is more difficult. In this situation, firms may adopt a play strategy, and a "build to play" strategy aimed at building and using resources (i.e., patented inventions) to secure access to externally developed technologies, and freedom to operate through non-pecuniary exchanges of IP and associated rights. A play strategy thus allows firms to achieve appropriability by using patents as a bargaining chip in the strategic factor market rather than in the product market. If the focal technological resource is connected to other technological resources that form the basis of the firm's sustainable competitive advantage (i.e., if the resources are a core technology of the firm), however, it will be more likely that the firm will try to protect its appropriability via a strategy that involves "build to fence" other core resources — i.e. to pursue a fence strategy. However, our findings highlight significant differences between technological leaders and laggards in the protection of core technologies. The adoption of a fence strategy as a response to competition in a core technology is driven by technological leaders. This result suggests that leaders have stronger incentives to protect their core assets compared with laggards.

Our findings highlight the heterogeneity in the mechanisms that firms can rely on to extract value from given resources, although in our case, this heterogeneity is sparked by the actions of rivals. As a starting point, the firm may accumulate technological resources to obtain economic rents in the product market, but the value of these resources is lower in the case of competition in the technology space. However, in this situation, the firm will be more likely to deploy the resource to alternative uses (e.g., cross-licensing negotiations) so that it may generate rents under these circumstances as well, albeit in a different fashion.

Our study contributes to the debate on open vs. proprietary innovation models. The open innovation literature identifies factors that spur firms to engage in knowledge exchange, e.g., rising R&D costs and market competition (Arora et al., 2001; Von Hippel, 2001; Chesbrough, 2003; Laursen and Salter, 2006). Our analysis suggests that technological competition may lead firms to share their IP assets with other patent owners. This finding indicates that openness is driven not only by the need to access external knowledge but also by the search for freedom to operate which is critical when the firm tries to accelerate its R&D activity vs. competitors. However, as discussed before, in the presence of competition for core technology patents firms resort to a fence strategy. Thus, a "closed" approach to IP management becomes likely if critical resources are at stake, and exclusion from the technology race could have dramatic effects on the firm's competitive advantage.

The findings from this study have implications for managerial practice. Our research suggests that when technological competition makes the traditional strategy of patenting a resource less suitable, managers can rely on either a play or a fence strategy to benefit from the pertinent technological resource. However, when making such a critical organizational choice, managers need also to factor into what extent the relevant technological resource is critical to the firm's appropriability and sustainable competitive advantage.

This study has several limitations that indicate opportunities for future research. While we think that the robustness of the results to several checks rules out a range of otherwise plausible alternative explanations and that the instrumental variable approach to an extent mitigates endogeneity problems, the cross-sectional nature of the data suggests caution about causal interpretation of the linkages between the main variables in our framework. Ideally, we would have liked to have analyzed the effects of within firm shifts in patent strategy due to technological competition, but the nature of our data does not allow for such an analysis. Also, while we think that our instrumental variable strategy is defendable on theoretical grounds, regarding the exclusion restrictions, we acknowledge that we cannot be perfectly sure that the exclusion restrictions are met.

Our analysis centers on data collected through an inventor survey and concerning single patent applications rather than firms' patent portfolios. Although we control for patent portfolio characteristics — size and core technology, it is likely that our patent strategy measures do not capture the firm's overall patent portfolio strategy. However, we think that our approach is suitable to address the research question in this paper for the following reasons. First, a patent portfolio level analysis would entail aggregation biases, whereas our focus on single patents allows identification of otherwise unobservable patent-specific characteristics correlated to patent use and the firm's perception of competitive pressure. Our focus on single patents is in line with earlier contributions that adopted a similar approach to investigate the determinants of the propensity to license, the relationships between the technological and business value of patents, and the reasons for patent non-use (Gambardella et al., 2007; Suzuki, 2011; Walsh et al., 2016). Second, focusing on specific patents could be an issue especially in the case of technologies such as electronics and semiconductors where cross-licensing negotiations typically involve the full patent package owned by each partner, in a given field-of-use (Grindley and Teece, 1997). However, even in these technological fields, patent litigation cases involving one or few infringed patents do exist. Consider, for example, the recent decision of the U.S. District Court for the Southern District of California which has found that Apple's iPhone 7, 7 Plus, 8, 8 Plus and X infringed 3 Qualcomm's patents (Qualcomm, 2019).

Another potential limitation of our data may be that inventors are not aware of the reasons for patenting the invention and the commercial exploitation of the patent. However, while inventors may have limited information about the overall patent strategy of their employer organization, in all probability they are informed about patents that protect inventions they contributed to develop. One reason being that firms often incentivize inventors by tying their reward to the commercial exploitability of patented inventions (Harhoff and Hoisl, 2007). Although our checks based on a random sample of inventors confirms that inventors have significant information about the use of the survey patent, future research could further explore the role of inventors in (and their level of information about) patent uses. Despite these limitations, we hope that this paper will be considered a first step toward advancing our understanding of firms' strategic responses to the onset of technological competition, in terms of use of IP rights linked to critical resources.

## CRediT authorship contribution statement

**Riccardo Cappelli:** Methodology, Software, Writing – original draft. **Marco Corsino:** Conceptualization, Methodology, Writing – original draft. **Keld Laursen:** Conceptualization, Methodology, Writing – original draft. **Salvatore Torrisi:** Conceptualization, Methodology, Writing – original draft, Supervision.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The authors do not have permission to share data.

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