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Linking inventions and new products: The influence of technology characteristics and the moderating role of firm capabilities and external environment

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Abstract

State-of-the-art. Past research in strategic management has argued that the commercialization of technological inventions is a key determinant of firm success (Cooper, 2000; Kumar and Jain, 2003). Specifically, the commercialization of firms? proprietary technologies via new products is a critical determinant of organizational performance and survival (Damanpour 1991, Artz et al. 2010). To date, most of the literature pointed out that invention commercialization via new products is mainly affected by firm capabilities (Zhou and Wu, 2010), human resources (Collins and Smith, 2006), and firm operating environments (e.g., Czarnitzki et al., 2012).

Research gap. This literature has largely neglected to consider the effects of the technological characteristics of an invention (except for Nerkar and Shane 2007), which can make it more (or less) suitable for being commercialized (e.g., Colyvas et al., 2002). Thereby, whether and to what extent technology characteristics affect the likelihood of commercializing proprietary inventions via new products, as well as how both firms? capabilities and external environment moderate their effects, remain an under investigated issue.

Theoretical arguments. In this project I will analyse firms? patent portfolios focusing on the relationships between their technological characteristics (breakthrough nature, scientific nature, industrial applicability) and the likelihood of being commercialized into viable products. Indeed, past studies stated that these characteristics influence the expectations of firms about the appropriability of the returns that would be earned from successful commercialization of the inventions (e.g., Shane, 2001), as well as they affect firms? value creation capabilities. Furthermore, the moderating effects of firms? specific characteristics (technological effort and internationalization) and external environment (market competitiveness) are also considered.

Method. The green energy sector is used as the research setting since both the development of technological inventions in this field and the demand for green products are sharply growing (Diaz-Rainey and Ashton, 2008; Albino et al., 2013). With this regard, I have collected data about all the patents successfully filed at the U.S.PTO. between 1970 and 2010 belonging to the green energy technological areas (about 50,000 patents), as identified by the IPC Green Inventory classification. The unit of analysis of the study is the patent portfolio developed by a firm in a given year and in a given

technological class (e.g., solar energy, energy storage, etc.). The dependent variable is the likelihood that a firm has subsequently introduced a product on the market in the same technological domain with a time lag of 3 years. The dependent variable will be operationalized through the use of trademark data. Indeed, a trademark has been considered to be related to the introduction of new products (Conley, 2013). In fact, a trademark is granted only if it exists a product on the market using it. Moreover, trademark data contain information about technological domain of technologies used in related product(s) and are publicly available for a long time series. Thereby, it has been possible to link the chosen unit of analysis with the number of trademarks registered by the same firm in the same technological domain, 3 years after the application of the patent portfolio. Trademark data has been collected using a keyword approach. First, I selected a set of keywords related to each technological domain using the description provided by the IPC green inventory. Then I searched for trademarks in the U.S.PTO. database containing the selected keywords and that are registered by the patent owners. After the search process, each trademark has been read in order to avoid false-positive results (about 3,500 trademarks were collected). Independent variables, moderating variables, and controls have been operationalized using patent bibliographic information (e.g., Lerner, 1994; Ernst, 2003) and online databases.
Results. The logit model has been applied for analysis of influencing factors. Preliminary results show that the breakthrough nature positively related to the introduction of new products, while the the industrial applicability has a negative effect. Looking at the moderating effects, market competitiveness negatively moderates the effect of both breakthrough nature and industrial applicability. Differently, firms? technological effort negatively moderates the effect of the breakthrough nature.
The present research will offer new strategic information, allowing to better understand the performance of firms at invention commercialization via new products by including new critical intervening variables, as technology characteristics (Nerkar and Shane, 2007).

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Linking inventions and new products: The influence of technology characteristics and the moderating role of firm capabilities and external environment

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Abstract

This study investigates whether technology characteristics influence firms' decision to turn their inventions into marketable products, by linking firms' technological portfolios with their related products on the market. Accordingly, I consider two technology characteristics that affect firms' value creation and value appropriation capabilities, as the breakthrough nature and the industrial applicability of inventions. Furthermore, I consider the moderating effects of competitive intensity, firms' technological effort and internationalization. Using the portfolios of both patents and trademarks owned by private companies and belonging the energy conservation sector, this study provides empirical evidence that technology characteristics explain the willingness of firms to commercialize proprietary inventions and that such a relationship is contingent on factors related to external environment and firms' capabilities.

INTRODUCTION

It is well know that firms commercialize their inventions in order to achieve the Schumpeterian rents that arise from the subsequent introduction of technological products on the market (Roberts 1999, Winter 1995, Nerkar and Shane 2007). Indeed, the introduction of new products is the necessary condition before achieving returns from the commercialized technologies (Zahra and Nielsen 2002), and it positively affects firms performance and survival (Damanpour 1991, Artz et al. 2010). Furthermore, nowadays, the number of technology-based products is rapidly growing, as well as the firms commercializing them (Pavitt 1998). However, exploiting owned technological inventions via new products is an uncertain process (Zahra and George 2002). Hence, understanding the process of technology commercialization, defined as "the process of acquiring ideas, augmenting them with complementary knowledge, developing and manufacturing saleable goods, and selling the goods in a market" (Mitchell and Singh 1996:170), has become a key strategic management issue (e.g., Zahra and Nielsen 2002). Accordingly, many scholars in different fields have attempted to study the most relevant factors needed to turn firms' inventions into marketable products. Past studies took into account firms' R&D efforts (Hoang and Rothaermel 2010, Vega-Jurado et al. 2008) and search strategies (Katila and Ahuja 2002, Li et al. 2013), organizational culture and structure (Souitaris 2002, Akgün et al. 2012, Zahra and Nielsen 2002), human resources' abilities, knowledge, and experience (Smith et al. 2005, Harryson et al. 2008),

environmental uncertainty and competitive intensity (Davila 2003, Radas and Božić 2009), and interfirm collaborations (Story et al. 2011, Quintana-García and Benavides-Velasco 2004). However, the effects of the attributes of the developed inventions have been often neglected. Specifically, I focus my attention on the characteristics of technologies that affect firms' ability to create value and then appropriate the created value, since both value creation and appropriation are sources of competitive advantage. Accordingly, depending on their characteristics, technologies influence firms' market potential (e.g. Chen et al. 2011), as well as become easier to be managed in the product development process or more appropriable (Gopalakrishnan and Damanpour 1994, James et al. 2013, Nerkar and Shane 2007). Thus, technology characteristics affect the expectations of firms about the returns after invention commercialization, and then the probability of firms to invest time and money in the exploitation of their technologies (Nerkar and Shane 2007). Nevertheless, whether and to what extent technology characteristics affect the likelihood of commercializing firms' proprietary technological inventions via new products remain an under investigated issue. In this work, I analyze the relationship between technology characteristics and the introduction of new products resulting from firms' technological portfolios by considering the breakthrough nature and industrial applicability of inventions. Furthermore, the moderating effects of firms' capabilities and external environment on this relationship are also analyzed. Indeed, firms differ in their ability to create value in base of their expertise in developing new technologies (Afuah 2002) or in base of their level of internationalization (Kafouros et al. 2008). Moreover, competitive intensity impacts on the product life-cycle and appropriability condition, hence affecting firms' decisions on what kind of technological inventions to embed in their new products (Li and Calantone 1998). See the conceptual model in Figure 1.
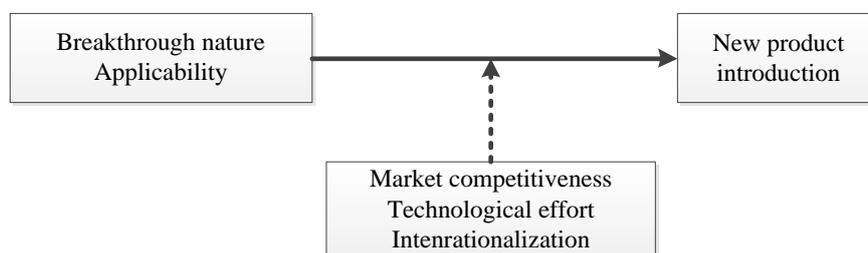

Figure 1. Conceptual model

This literature gap is mainly related to a lack of data on the inventions owned by firms, but especially on the new products resulting from them. With this regard, I propose a new methodological approach which links firms' patent portfolios with their related trademark portfolios. Accordingly, patents are a good proxy to assess firms' technological stock. Furthermore,

literature has suggested different measures which are useful to assess some characteristics of the patented inventions (Nerkar and Shane 2007, Trajtenberg et al. 1997, Lerner 1994, Hall et al. 2001). Moreover, patents can be classified in respect to a given technological domain through well-defined classifications, such as the IPC classification and US classification. Differently, trademarks are marks used by products on the market. In the intellectual property (IP) and brand management literature (e.g., Low and Fullerton 1994), they have been seen as means to establish and maintain firms' reputation (Rose and Thomsen 2004). However, in the recent years, some researchers have used trademark data as a measure of innovation (see Mendonça et al. 2004). Particularly, trademarks have been considered to be related to firms' downstream capabilities and the introduction of new products (Fosfuri and Giarratana 2009, Conley et al. 2013). Moreover, it is possible to assess the technological domain of the products using a specific trademark. Thus, I employ these two sets of data to analyze the proposed relationship (more details are provided in the "data and methods" section).

THEORETICAL BACKGROUND AND HYPOTHESES

Value creation and appropriability

We build herein on the concepts of value creation and value appropriation to explain how the characteristics of technological inventions affect the invention commercialization process via new products. Indeed, the primary intention of any business entity in order to attain a sustained competitive advantage is value creation (Moran and Ghoshal 1996). Schumpeter (1934) first introduced the concepts of economic development and new value creation through the process of technological change and innovation. Specifically, in the Schumpeterian view, technologies and the novel combinations of these resources are at the basis of value creation (see also Lepak et al. (2007). Accordingly, Lippman and Rumelt (2003:922) stated that "Owning a valuable resource is a good thing, and making its value higher is a good thing". In fact, value creation influences the potential magnitude of the advantage which firms can achieve. However, value appropriation capabilities are responsible for the entity of the captured advantage. Thus, both value creation and value appropriation are important tasks for firms. Nevertheless, the strategic management literature also pointed out that firms do not necessarily appropriate the created value (Mizik and Jacobson 2003). Rather, it is not uncommon that they have to share this value with other stakeholders, such as competitors, or society (Coff 1999, Makadok and Coff 2002). Of course, this difference between the created and appropriated can provide little incentive to exploit proprietary resources (e.g. technologies) (Lepak et al. 2007). Hence, the firms' possibility to both create and appropriate value

from their proprietary technologies is required for continuing the invention commercialization process. Indeed, at the basis of invention commercialization is the willingness of firms to turn their technologies into marketable products (Schumpeter 1934). This willingness is in turn dependent on the firms' capability to successfully create and appropriate the value from the introduced technological products (Nelson 1959, Arrow 1962). Thus, factors that improve the likelihood of value creation and the appropriation of returns from the commercialization process, such as technology characteristics (James et al. 2013, Gilbert 2006), push firms to proceed with the exploitation of their inventions and the subsequent introduction of new products (Levin et al. 1987, Nerkar and Shane 2007).

The breakthrough nature of inventions

Looking at the technological importance of inventions, I refer to breakthrough inventions as those technologies which are the foundation for many subsequent technological development (Trajtenberg 1990, Rosenkopf and Nerkar 1999, Podolny and Stuart 1995, Ahuja and Lampert 2001). Specifically, the introduction of breakthrough technologies significantly impact the market in which they are introduced or the product category (Van ittersum et al. 2006). Moreover, they cause the establishment of new markets and contribute to the innovation diffusion (Achilladelis and Antonakis 2001), as well as open up opportunities for interdisciplinary combinations of different inventions (Björkdahl 2009, Granstrand 2001). Accordingly, Porter (1985) argued that new value is created when firms propose new ways of doing things using new methods, and new technologies. Moreover, breakthrough inventions lead to the introduction of products sensibly different to the current offering (Rogers 2003) whose benefits are not provided by any other existing technologies, hence increasing the "potential use value" to the user (Amabile 1996). In addition, these inventions can increase the appropriability of returns after commercialization since they provide first mover and learning curve advantages (Levin et al. 1987, Lieberman and Montgomery 1988). Indeed, breakthrough technologies are not developed around previous inventions. Hence, there is less knowledge available which can lead to imitative behaviors from other companies (Nevens 1990). Hence, the probability to appropriate returns from the commercialization of those inventions increases, and so the likelihood for firms to invest in those technologies (Ahuja and Lampert 2001, Lepak et al. 2007). Therefore,

Hypothesis 1: The breakthrough nature of inventions is positively related to the introduction of new products.

The industrial applicability of inventions

Industrial applicability refers to the property of inventions to be employed in products belonging different technological domains (Chen et al. 2011). As a consequence, technologies which are more applicable are of interest because of their potential to create value in a wider range of alternative sectors (Keenan 2003). Nevertheless, from a capability-based view perspective (e.g., (Barney 1991), firms should put emphasis on a narrower range alternatives because of a lack of all the resources and capabilities needed to support such diversification effort (Penrose 1959, Gambardella and Torrisi 1998, Von Tunzelmann 1998). Indeed, diversification might turn into diseconomies of scope generated by an over diversification (Lin et al. 2006), as well as increases costs of entry in new business domains (Porter 1987), bureaucracy, and control (Hill 1994). Moreover, focusing on different technological domains can result in an increase of the complexity of the value creation process (Capaldo and Messeni Petruzzelli 2011) as a consequence of the probability to generate too many ideas compared to firms' ability to screen and select them (Koput 1997). Hence, this higher complexity will likely raise the uncertainties about the overall process of turning inventions into marketable products (Tushman and Rosenkopf 1992). In addition, Montgomery and Wernerfelt (1988) stated that potentially valuable resources can realize value in only a few applications. This has been further confirmed by empirical evidence showing that large technological diversification does not lead to large product diversification (Gambardella and Torrisi 1998, Giuri et al. 2004). Furthermore, the interdisciplinary nature of the exploitation of this type of technologies is subjected to technology spillover (Zhang and Song 2009). In fact, more generic technologies are seen as public goods which are difficult to introduce the perfect market (Zhang and Song 2009). Hence, they are less appropriable. Accordingly, Gambardella et al. (2007) argued that firms that have developed different types of applicable technological inventions are more involved in technology licensing because of the danger of strengthen the position of their competitors. Therefore,

Hypothesis 2: The industrial applicability of inventions is negatively related to the introduction of new products.

The moderating role of competitive intensity

A high level of competitive intensity is characterized by a severe price wars, heavy advertising, and diverse product alternatives (Porter 1980). In addition, in this market condition, the fruits of innovation often spill over the society (Arrow 1962). Indeed, the more competitors in the market, the more actors take advantage of the same resources, thus lowering the value appropriated by the innovator (Lepak et al. 2007, Arrow 1962). As a result, society benefits from lower prices (Schumpeter 1942), as well as the market becomes more uncertain and unpredictable (Auh and

Menguc 2005, Gupta et al. 2006). Thereby, companies put their attention to cost efficiencies strategies in order to have more resources to compete and trying to their performance (Gatignon and Xuereb 1997, Day 1994). Hence, the willingness of firms to invest time and money to exploit breakthrough or more applicable technologies decreases. Indeed, imitation is generally preferred against the exploration of new opportunities (Day 1994, Kim and Atuahene-Gima 2010, Zheng Zhou 2006). Furthermore, competition requires firms to respond fast and concurrent in respect to their competitor (Kim and Atuahene-Gima 2010), thus claiming a steady stream of innovations (Sorescu et al. 2003). Hence, managers do not have the time to specify in advance the technologies that will prevail (Augusto and Coelho 2009). Accordingly, companies focus on incremental innovative activities aiming at developing new products in relatively short time (Ali 1994) whose outcome is more predictable in order to limit potential losses (Voss et al. 2008). Hence, inventions which are new to the product development process or which need new resources to be exploited might be less considered in the commercialization process. In light of the above reasoning, I hypothesize:

Hypothesis 3: Competitive intensity weakness the relationship between the breakthrough nature of inventions and new product introduction.

Hypothesis 4: Competitive intensity weakness the relationship between the industrial applicability of inventions and new product introduction.

The moderating role of technological effort

Each company has certain firm-specific technological resources. Technological capabilities refer to the capabilities of firms to select the most appropriate technologies to create value for customers, as well as to exploit the selected technologies (Fransman 1984, Afuah 2002). Accordingly, value creation is dependent upon firms' capabilities to combine and recombine technologies (Schumpeter 1939), as well as to understand the way these components have to be linked together (Henderson and Clark 1990) in order to offer new products. These skills, knowledge and experience are acquired and accumulated mainly through technological efforts. Therefore, technological efforts are mechanisms for accumulation of technological capabilities that can allow firms to better manage breakthrough or more complex technologies. Accordingly, it has been argued that the more explicit and purposeful the technological efforts, the deeper the capabilities accumulated (Bell 1984). Therefore,

Hypothesis 5: Technological effort strengthens the relationship between the breakthrough nature of inventions and new product introduction.

Hypothesis 6: Technological effort strengthens the relationship between the industrial applicability of inventions and new product introduction.

The moderating role of internationalization

Internationalization refers to the extent to which firms operate outside their national boundaries (Kotabe et al. 2002). According to Kobrin (1991), it helps firms to develop and acquire new resources to create value from their technologies. For instance, dispersed R&D teams are facilitated in accessing information from a wider range of sources and new different markets (von Zedtwitz and Gassmann 2002, Kurokawa et al. 2007). In addition, creativity is fostered because of the possibility to exchange ideas between scientists of different countries and cultures (Kafouros et al. 2008, Hitt et al. 1997) or hire the most skilled workers (Cheng and Bolon 1993). This can lower the efforts needed to handle the development of new products based on radical or generic inventions. Nevertheless, internationalization increases the costs of coordination and leads to the risk of knowledge spillover to competitors (Granstrand et al. 1993, Sanna-Randaccio and Veugelers 2007). However, these drawbacks are mitigated by the fact that firms can better appropriate the created value as they increase the number of markets they serve. Indeed, they can better react to changes in needs of their customers (Kafouros 2006) and can spread their costs along many customers (Kafouros et al. 2008). Thereby, firms may be more available to invest in the exploitation of radical or more applicable technologies. In addition, the possibility to obtain complementary assets increases (Teece 1986), as well as the risks related to fluctuations and business cycle specific to a single market are limited (Kafouros et al. 2008). Therefore,

Hypothesis 7: Internationalization strengthens the relationship between the breakthrough nature of inventions and new product introduction.

Hypothesis 8: Internationalization strengthens the relationship between the industrial applicability of inventions and new product introduction.

DATA AND METHODS

Industry setting

The energy conservation sector is used as the research setting. Indeed, since the publication of the "Limits to Growth" (Meadows 1972), going through the born of the concept of sustainable development (WCED 1987), the idea that the depletion of natural resources has a negative effect on the ability to meet human needs and foster economic activity has drastically grown (OECD and IEA 2011). Specifically, the energy sector is greatly part of this issue given the increased level of electricity consumption. Thus, as required by the long-term decarbonisation goals recently set (e.g. Europe 2020 targets), shifting to a "greener" approach in the way I consume energy is needed (OECD and IEA 2011). With this regard, technologies are recognized as crucial in moving towards low-carbon and resource efficient economies and societies (Stocker et al. 2013) by promoting energy savings on the demand side (Blok 2005, Lund 1999) and efficiency improvements in the energy production and manufacturing processes (Lior 1997, Lior 2002). Accordingly, the development of energy conservation technologies has raised in the last decades (Albino et al. 2013). However, these technologies must be turned into new viable products and diffused on the market. In fact, as stated in the Green Paper on Integrated Product Policy (EC 2001), sustainable development can be achieved by introducing green products. Accordingly, the demand for these products is sharply growing (Diaz-Rainey and Ashton 2008). Thus, in this work I refer to the technologies belonging the energy conservation sector, as well as to the products embedding them.

Data collection

In order to collect data about technologies and products belonging to the energy conservation sector I followed a two stage approach. First, I identified all the patents belonging the energy conservation sector. Indeed, intellectual property protection plays a relevant role in the energy sector (OECD 2012). Accordingly, I have collected data about all the patents successfully filed at the U.S.PTO. between 1970 and 2007 belonging to the "Energy conservation" class (21,615 patents), as identified by the International Patent Classification (IPC) Green Inventory[1]. Specifically, the IPC Green inventory was developed by the World Intellectual Property Organization in 2008. It provides a link between the Environmentally Sound Technologies[2] (ESTs) and the IPC classification. More in detail, it divides ESTs in seven green technological classes, which are in turn divided into a hierarchical sets of subclasses. In this paper, I mainly refer to the "Energy conservation" class and its subclasses (see Table 1). Thus, I searched for all the patents placed in this class on the basis of the suggested IPC codes. Once identified the patents, I collected all the related information, namely first-level subclass, filing and issue year, citations made and received, claims, and information

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[1] See http://www.wipo.int/classifications/ipc/en/est/
[2] ESTs "are technologies that have the potential for significantly improved environmental performance relative to other technologies" (Chapter 34 of Agenda 21)

about all the inventors and assignees. Then, I excluded all the patents which are not owned by a company. Moreover, I considered the patents whose assignee has patented at least 5 inventions in this category in order to leave out firms that are not focused in the development of "Energy conservation" technologies. Of course, I previously corrected assignees' names since it is not uncommon to find the same company registered with different names (e.g "Procter and Gamble", "Procter & Gamble", "P&G"). The final sample consists of 12,156 patents. Since there is not a one-to-one relationship between an invention and a product, instead of using the single patent, the unit of analysis of the study is the patent portfolio developed by a firm in a given year and in a given technological subclass (see the Appendix), thus yielding a total of 3,806 observations. Second, I used the introduction of trademarks as a proxy for the introduction of new products. Indeed, a trademark identifies and distinguishes the source of the goods or services[3]. Furthermore, trademark owners must demonstrate that they have introduced a product on the market using it, otherwise the trademark is cancelled. Accordingly, scholars have recently employed trademarks as a measure of firms' downstream capabilities (e.g., Fosfuri and Giarratana 2009). Moreover, trademarks have been considered to be related to the introduction of new products (Conley et al. 2013). In addition, trademark data contain information about the technological domain of the technologies used in the related product(s) and are publicly available for a long time series. Thereby, it has been possible to search trademarks owned by the patent owners which are related to the same technological subclasses of a patent portfolio. However, differently from patents, it doesn't exist a defined technological classification of trademarks. Hence, in order to find trademarks linked to products in the energy conservation sector, I adopted a keyword approach. First, I selected a set of keywords related to each technological subclass using the descriptions provided by the IPC green inventory. Then, I searched for trademarks in the U.S.PTO. database containing the selected keywords and that are registered by the patent owners. After the search process, each trademark has been read in order to avoid false-positive results. The final sample of consists of 2,228 trademarks registered between 1970 and 2012. Thus, it has been possible to link the chosen unit of analysis with the trademarks registered by the patent owners in the same technological domain.

Table 1. "Energy conservation" subclasses and related IPC codes.

Energy conservation	
Subclasses	IPC codes
Storage of electrical energy	B60K 6/28, B60W 10/26, H01M 10/44-10/46, H01G 9/155, H02J 3/28, 7/00, 15/00
Power supply circuitry	H02J, H02J 9/00
Measurement of electricity consumption	B60L 3/00, G01R
Storage of thermal energy	C09K 5/00, F24H 7/00, F28D 20/00, 20/02

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[3] See http://tess.uspto.gov

Low energy lighting	F21K 99/00, F21L 4/02, H01L 33/00-33/64, 51/50, H05B 33/00
Thermal building insulation, in general	F21K 99/00, F21L 4/02, H01L 33/00-33/64, 51/50, H05B 33/00, E04C 1/40, 1/41, 2/284-2/296, E06B 3/263, E04B 2/00, E04F 13/08, E04B 5/00, E04F 15/18, E04B 7/00, E04D 1/28, 3/35, 13/16, E04B 9/00, E04F 13/08
Recovering mechanical energy	F03G 7/08, B60K 6/10, 6/30, B60L 11/16

Measures

Independent variable

New product introduction (NPI). I operationalized new product introduction as the likelihood that a firm has registered at least one trademark during the 5 years after the development of a patent portfolio in the same technological subclass. Thus, this is a binary variable which can assume a value of either 1 or 0. The reason of this choice lies in the fact that a trademark not always represents a single product. Indeed, a firm may register only one trademark but it may introduce different products using it. Differently, a firm may register a trademark which is related to the introduction of one specific product. Hence, counting the number of trademarks can lead to misleading interpretation of the model.

Explanatory variables

Breakthrough nature (BreakNat). This variable considers the number of breakthroughs developed in a patent portfolio. Specifically, following the measure proposed by Ahuja and Lampert (2001), I identified the top 1% of highly cited patents in the sample for each year. Then, I marked these patents as breakthroughs. Finally, I count the number of breakthrough patents in each patent portfolio.

Industrial applicability (IndApp). Following Lerner (1994), for each patent I counted the number of different 3-digit US classes that a patent has on its front page in order to measure the number of its different potential commercial applications. Then, for each portfolio, I average the number of different 3-digit US classes had by its patents.

Moderating variables

Competitive intensity. I measured competitive intensity following the measure of Competitive Technological Position (CTP) proposed by Ernst (2003). This variable is operationalized as follows:

$$CTP = \frac{P_{it}}{P_t}$$

Where P_{iF} is the number of patents successfully filed by the firm i in year t, belonging the "Energy conservation" class, while P_t is total number of patents successfully filed in the observation year belonging the "Energy conservation" class.

Technological effort (TechEff). Firms' technological effort is measured by counting the number of patents successfully filed in the 5 years prior to the development of a patent portfolio and belonging the "Energy conservation" class.

Internationalization

We compute internationalization using two different measures. The first one, R&D internationalization (R&Dint), looks whether firms are involved in dispersed R&D activities. The second, market internationalization (MrktInt), assesses the extent to which firms operates in different markets. This choice is justified by past literature, which finds that these two approaches to internationalization are not always mutually pursued (von and gasman 2002). Specifically:

$$R\&DINT = 1 - \sum_k (\frac{n_k}{n})^2 \text{ (Singh 2008)}$$

where n is total number of patents that the firm has successfully applied for during the 5 years prior to the development of a patent portfolio, and n_k refers to the subset of these arising from the first inventor being in country k. As country, I refer to United states, Germany, Japan, etc.. Differently, MrktInt is computed as the number of different countries in which a firm operates (Kotabe et al. 2002).

However, I am still collecting data to calculate these variables. Thereby, in this paper, I only test Hypotheses 1-6.

Controls

Other factors may influence the commercialization of firms' own technologies via new products. Indeed, I constructed several sets of control variables. I controlled for the dimension of the teams involved in the development of a patent portfolio (TeamSize) by averaging the number of inventors of each patent within each portfolio, as well as for the average number of claims (Claims) of the patents in a portfolio. Likewise, I averaged the number of a patent's scientific-based citations to compute the scientific nature (SciNat) of a patent portfolio. Furthermore, I included firms size (Size) by measuring the natural log of number of employees, as well as business diversification (BusDiv) by counting the number of different SIC codes assigned to a firm. I also controlled for firms'

scientific attitude (SciAtt), as measured by the natural log of the number of articles published on journals indexed in SCOPUS database in the 5 years prior the development of a patent portfolio. Furthermore, I included two binary variables that consider whether patent owners are present in the stock market (StkMkt), and whether they are a parent or a subsidiary company (Ownership). Finally, to account for the possibility of technology subclass effects I created a set of 6 dummy variables (dummy_subclass) to reflect the 7 subclasses that cover the "Energy conservation" class.

ANALYSES AND RESULTS

The dependent variable has a binary outcome of 1 or 0. Hence, I employed a logistic regression model to test our hypotheses (Long 1997):

$$\Pr(y = 1|x) = \frac{\exp(\alpha + \beta x)}{1 + \exp(\alpha + \beta x)},$$

where y is the dependent variable and x stands for the explanatory variables. I report both Pseudo R2, LR Chi2, and Log-likelihood, together with the results of the logistic regression.

Table 2 shows basic descriptive statistics and correlations of all the variables. Correlations are not particularly high. Table 3 presents the results of the hypothesis testing. I used hierarchical models, with Model 1 serving as the baseline model that includes all the control variables, Models 2–6 serving as partial models that introduce the independent variables and each of the interaction term, and Model 7 serving as the full model that incorporates all variables. I relied on the partial models for testing our hypotheses since the value of the variance inflation factor (VIF) for the last model exceed the critical value of 10 (Kleinbaum et al. 1998). Model 1 reveals that he probability to introduce new products increases with the level of the scientific nature of invention (β = .016, p<0.05), the number of claims (β = .008, p<0.05), the dimension of teams involved in the development of inventions (β = .146, p<0.001), the presence on the stock market (β = .316, p<0.001), and the scientific attitude of firms (β = .170, p<0.001). Differently, being a parent company (β = -.606, p<0.001) (Zahra 1996) decreases the probability to introduce new products. Model 2 tests the main effect of the two explanatory variables. Per Model 2, both Hypothesis 1 and Hypothesis 2 are supported. Indeed, the breakthrough nature of inventions is positively related to the probability to introduce new products (β = .500, p<0.01), while the applicability of invention has a negative effect on the invention commercialization vie new products (β = -224, p <0.001). Model 3 and 4 test the moderating effect of competitive intensity on the breakthrough nature and the industrial applicability of inventions, respectively. The results support Hypothesis 3 (β = -

97.284, p<0.01) and 4 (β = -27.925, p<0.05). Lastly, Hypothesis 5 and 6 are not supported. In fact, technological effort negatively moderates the positive effect of the breakthrough nature of inventions on new product introduction (β = -.021, p<0.1), while, despite the positive sign, the coefficient of the interaction term between technological effort and applicability is not significant.

DISCUSSION AND CONCLUSION

The present research offers new strategic information, allowing to better understand the performance of firms at commercializing proprietary technological inventions via new products by including new critical intervening variables, as technology characteristics (Nerkar and Shane 2007), and by considering the moderating role of competitive intensity and firms' technological effort. Linking patent portfolios of firms involved in the development of energy conservation technologies with their related trademark portfolios, I showed that the breakthrough nature and industrial applicability of inventions influence the likelihood that firms exploit their technologies. Moreover, these effects suffer the influence of both firms' capabilities and external environment.

The theoretical implications of this work are threefold. First, I add empirical evidence that the characteristics of technological inventions do affect the likelihood of firms to commercialize them. Specifically, this is in line with theories which suggest that factors that increase value creation and value appropriation capabilities push firms to invest in the commercialization process (James et al. 2013, Gilbert 2006). Furthermore, I extend the study of invention commercialization via new products considering the actual internally owned inventions of firms rather than those acquired from research institutes (see Nerkar and Shane 2007). Hence, I posit that technological inventions themselves, rather than just firm capabilities and external environment, have to be considered in the strategic decision of firms to undertake a new product development project. Second, the integration of competitive intensity and firms' technological effort suggests that the ability to create and appropriate value through firms' resources (e.g. proprietary technologies) depend on external environment and firms' specific capabilities (Barney 1991). Third, our study proposes a new proxy for the introduction of new products, mainly based on the property of trademarks to exist only if a product on the market is using it. Indeed, the innovation construct has been often operationalized as R&D intensity or as number of patents. However, these constructs do not reflect the actual results of innovation activities. Rather, they can be viewed as input to innovation. This is especially true since firms are more active in the product market (Pavitt 1998). In addition, I posit that by using trademark data it is possible to assess whether firms' owned technologies are implemented in products that have reached the market.

Table 2. Descriptive statistics and correlations

	Min	Max	Mean	Dev. Std.	NPI	BreakNat	IndApp	CTP	TechCap	SciNat	Claim	TeamSize	Size	BusDiv	Ownership	StkMkt	SciAtt
NPI	0	1	0.15	0.362	1	.095**	-.033*	.064**	.231**	.092**	.032*	.114**	-.032	-.027	-.030	.077**	.118**
BreakNat	0.0	6.0	0.045	0.281	.095**	1	.028	.031	-.010	.062**	.057**	.045**	-.047**	-.012	-.001	-.022	.003
IndApp	1.0	8.0	1.802	0.874	-.033*	.028	1	.051**	-.070**	.043**	-.012	.060**	.017	-.035*	.039*	-.001	.010
CTP	0.0	0.095	0.003	0.005	.064**	.031	.051**	1	.330**	-.065**	-.073**	.006	.270**	.140**	.126**	.077**	.189**
TechEff	0.0	175.0	6.932	18.754	.231**	-.010	-.070**	.330**	1	.004	-.061**	.074**	.233**	.167**	.068**	.089**	.184**
SciNat	0.0	152.0	2.297	6.755	.092**	.062**	.043**	-.065**	.004	1	.138**	.143**	-.135**	-.064**	-.053**	-.028	-.054**
Claim	0.0	266.0	11.447	12.141	.032*	.057**	-.012	-.073**	-.061**	.138**	1	.050**	-.207**	-.040*	-.083**	-.071**	-.074**
TeamSize	1.0	15.0	2.416	1.406	.114**	.045**	.060**	.006	.074**	.143**	.050**	1	.032	-.063**	.006	.060**	.011
Size	0.0	14.070	9.449	2.525	-.032	-.047**	.017	.270**	.233**	-.135**	-.207**	.032	1	.184**	.246**	.301**	.225**
BusDiv	1.0	3.0	1.193	0.444	-.027	-.012	-.035*	.140**	.167**	-.064**	-.040*	-.063**	.184**	1	.028	-.032*	.024
Ownership	0.0	1.0	0.668	0.471	-.030	-.001	.039*	.126**	.068**	-.053**	-.083**	.006	.246**	.028	1	.331**	.128**
StkMkt	0.0	1.0	0.355	0.479	.077**	-.022	-.001	.077**	.089**	-.028	-.071**	.060**	.301**	-.032*	.331**	1	.141**
SciAtt	0.0	8.228	0.712	1.881	.118**	.003	.010	.189**	.184**	-.054**	-.074**	.011	.225**	.024	.128**	.141**	1

*p<0.05; **p<0.01

Table 3. Results for logistic regression analyses

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
BreakNat		.500**	.912***	.464***	.653***	.514***	.957***
IndApp		-.224***	-.246**	-.169**	-.187**	-.203**	-.183**
CTP x BreakNat			-97.284**				-78.350*
CTP x IndApp				-27.925*			-12.865*
TechEff x BreakNat					-.021+		-.016
TechEff x IndApp						.002	.004
CTP			46.576***	97.505***			37.464+
TechCap					.028***	.023***	.0211**
SciNat	.016*	.016*	.015*	.016*	.013*	.013*	.012+
Claim	.008*	.008*	.007*	.008*	.010*	.010*	.009*
TeamSize	.146***	.146***	.141***	.140***	.116***	.117**	.112***
Size	-.025	-.020	-.039	-.040	-.066	-.068	-.071**
BusDiv	.065	.066	-.003	-.013	-.277	-.280	-.289*
Ownership	-.606***	-.605***	-.633***	-.629***	-.616***	-.616***	-.632***
StkMkt	.316**	.329**	.344**	.354**	.383**	.386**	.385**
SciAtt	.170***	.172***	.166***	.160***	.152***	.149***	.152***
dummy_subclass	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R2	0.080	0.089	0.097	0.096	0.142	0.141	0.144
Pseudo Log-likelihood	-1390.02	-1376.95	-1364.10	-1365.69	-1296.43	-1297.88	-1292.27
Wald Chi2	242.08***	268.21***	293.92***	290.73***	429.26***	426.37***	437.58***

+$p<0.1$; *$p<0.05$; **$p<0.01$; ***$p<0.001$

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APPENDIX – UNIT OF ANALYSIS DEFINITION

Let Table A1 represents our dataset of patents. For each patent, it is shown the assignee, filing year and technological subclass (the other bibliographic information are not reported). Our unit of analysis is the patent portfolio owned by a specific company, which has been developed in a given year and belongs to a specific technological subclass. Thereby, the first observation is composed by the first three patents since they are all owned by firm A, developed in 2000, and classified in the "Low energy lighting" subclass. Differently, the fourth and fifth patent are still owned by company A and filed in 2000, but they belong to a different subclass. Hence, they constitute the second observation. Again, since the sixth and seventh patent differ from the fourth and fifth respect to the filing year and from the first three patents respect to the technological subclass, they form the third observation. Finally, the last observation include the last three patents, which are those owned by company B, filed in 2005, and classified in the "Thermal building insulation" subclass. Table A2 shows a summary of the 4 observations.

Table A1.

Patent number	Assignee	Filing year	Subclass
1	A	2000	Low energy lighting
2	A	2000	Low energy lighting
3	A	2000	Low energy lighting
4	A	2000	Thermal building insulation
5	A	2000	Thermal building insulation
6	A	2002	Thermal building insulation
7	A	2002	Thermal building insulation
8	B	2005	Thermal building insulation
9	B	2005	Thermal building insulation
10	B	2005	Thermal building insulation

Table A2.

ID portfolio	Company	Filing year	Subclass	Number of patents
1	A	2000	Low energy lighting	3
2	A	2000	Thermal building insulation	2
3	A	2002	Thermal building insulation	2
4	B	2005	Thermal building insulation	3