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Determinants of firms' patenting or not patenting behaviors

Kuo-Feng Huang [a,*], Tsung-Chi Cheng [b]

[a] Department of Business Administration, National Chengchi University, 64, Sec. 2, Zhi-Nan Road, Taipei 116, Taiwan
[b] Department of Statistics, National Chengchi University, 64, Sec. 2, Zhi-Nan Road, Taipei 116, Taiwan

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ABSTRACT

We distinguish between two firm patenting behaviors ('never patent' and 'always patent') and present a two-factor (capability and willingness) patenting behavior framework to enrich existing research. We examine innovative activities on 165 Taiwanese information and communication technology firms by using a zero-inflated Poisson regression model. Our results suggest that determinants of increasing probability of patenting are not completely the same as ones of decreasing probability of not patenting. Moreover, while capability factors are positively associated with propensity to patent, willingness factors moderate the relationship between capability factors and propensity to patent.

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Introduction

Experts agree that intellectual property protection is a necessary and very important mechanism for protecting firm competitiveness (Amara et al., 2008; Teece, 2000), since risks of unanticipated knowledge leakage or imitation are always present (Falvey et al., 2006). Companies gain effective technology protection through intellectual property laws and other technology protection actions that mitigate such risks as firms commercialize innovative products in the marketplace (Cohen et al., 2000),

* Corresponding author. Tel.: +886 2 29393091; fax: +886 2 29398005.
E-mail addresses: kfhuang@nccu.edu.tw (K.-F. Huang), chengt@nccu.edu.tw (T.-C. Cheng).

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particularly in the fast-changing high-tech industries[1] (Nonaka and Teece, 2001; Teece, 2000), such as the semiconductor sector (Cohen et al., 2000; Grindley and Teece, 1997; Hall and Ziedonis, 2001; Reitzig, 2003; Rivette, 1993) and biotechnology sector (Baum and Silverman, 2004; Zucker et al., 1998, 2002). Several technology protection mechanisms are available, including patent, copyright, and trademark strategies (Grindley and Teece, 1997). Patenting, however, is one of the most important technology protection mechanisms employed by innovative firms both in developed countries such as the US and Japan (Cohen et al., 2002) and in emerging countries such as China (Zhao, 2006). Empirical studies have suggested that in addition to increasing incentives for innovate products and processes (Cohen et al., 2000, 2002; Kingston, 2001; Levin et al., 1987), patenting can prevent competitors from duplicating patented research and technologies (Cohen et al., 2000, 2002; Kingston, 2001; Levin et al., 1987), signal a company's entry into new innovative areas or markets (Harabi, 1995; Robertson et al., 1995), facilitate cross-licensing activities (Cohen et al., 2002; Gambardella et al., 2007; Kingston, 2001), increase the business evaluation required for mergers or acquisitions (Puranam and Srikanth, 2007), prevent others from duplicating patents (Walsh et al., 2003), or secure freedom to operate (Walsh et al., 2003). All of these motivations, in the long run, help firms benefit from the protection of innovation results. In the short term, patent trolls collect patents to sue other companies (Cohen et al., 2000), as was the case in litigations between Apple and Samsung, or to delay the technological development of competitors (Gómez-Uranga et al., 2014). Google, for instance, bought out Motorola not only to make use of the Motorola's research and development (R&D) resources but also to use Motorola's patents to block other wireless competitors (Vaughan-Nichols, 2011).

In order to sustain competitive advantage in dynamic markets via patenting, firms must nurture innovation capabilities (Jacobson, 1992). A variety of technological capabilities enables firms to innovate and then increase propensity to patent. Prior studies have confirmed a positive relationship between these capabilities, such as R&D and resource allocation capabilities (Yam et al., 2004), and innovation (normally empirically measured by number of patents) (Walsh and Linton, 2002).

In addition to technological capabilities, other factors, which affect firms' possibility to patent, also have been investigated in prior studies. These include firm size (Arundel and Kabla, 1998; Brouwer and Kleinknecht, 1999; Chabchoub and Niosi, 2005), R&D expenses (Suzuki et al., 2006), secrecy degrees (Arundel and Kabla, 1998), geographical clustering patterns (Chabchoub and Niosi, 2005), product mix combinations (Chabchoub and Niosi, 2005), sector differences (Cohen et al., 2000), and patent portfolio races (Hall and Ziedonis, 2001). However, an inquiry of why firms decide not to patent has somewhat received less attention. Firms that never patent are normally regarded as expressing no, or at least limited, interest in patenting to keep innovations undisclosed (Arora and Ceccagnoli, 2006). Alternatively, firms may decide not to patent simply due to legal costs involved, such as high patent maintenance fees (Graevenitz et al., 2013; Grupp and Schmoch, 1999). High patent application and maintenance costs especially prevent startup firms, which typically exhibit resource shortages (Hite and Hesterly, 2001), or manufacturing-only firms (i.e., original equipment manufacturer, OEM), which normally have low margins (Dedrick et al., 2010), from patenting unless absolutely necessary. Moreover, firms may operate in legal environments characterized by patent imitation and costly litigation charges, or firms may engage in low differentiation environments (as may be the case in some contract manufacturing sectors), rendering innovation less attractive. As a result, firms have less incentive to patent. However, firms that never patent are not necessarily those void of innovation capabilities or strategies. Thus, the main purpose of this paper is to differentiate the attributes affecting patenting or not patenting.

Most prior studies have attempted to explore which factors affect propensity to patent. For instance, Mansfield (1986) identified differences in patent propensity over industries and time, while Griliches (1988) asserted that business cycles shape patent propensity. Brouwer and Kleinknecht (1999) found that firms' propensity to patent is significantly higher among R&D collaborators, and varies across sectors and different firm sizes. Arundel and Kabla (1998) suggested that propensity to patent increases with firm size, and perceived patents as an important means of preventing

[1] High-tech firms are characterized by investing a larger fraction of their budget in R&D activities (Czarnitzki and Thorwarth, 2012). In fast changing industries, rapid technological change causes knowledge and capabilities to become obsolete more rapidly than in other industries (Christensen et al., 1998).

competitors from replicating both product and process innovations. Moreover, both Brouwer and Kleinknecht (1999) and Arundel and Kabla (1998) found patent propensity to be lower in the case of process innovations when compared to product innovations. Hu (2010) found that competitive threats among competitors intensify the propensity to patent for foreign firms in China. As can be seen, most of the aforementioned determinants of propensity to patent are endogenous (i.e., firm-level factors) or exogenous (i.e., environmental factors). Although these fruitful discussions extend our understanding of determinants of firms' propensity to patent, what is missing here is an integrated framework to explain these determinants more systematically.

In our research, we propose that two factors may affect a firm's propensity to patent: capability factors and willingness factors. Firms first need to possess a degree of organizational capacity or competence to innovate, called 'capability factors' (i.e., endogenous factors), such as firm size (Arundel and Kabla, 1998; Brouwer and Kleinknecht, 1999), and then may possibly patent these innovated outputs. In addition to capability factors, firms also need to have a willingness to patent these innovations, called 'willingness factors' (i.e., exogenous factors), such as external collaborations (Brouwer and Kleinknecht, 1999) or competitive threats (Hu, 2010)). A higher degree of willingness may increase firms' likelihood to patent. To summarize, firm patenting propensities are determined by both firm capabilities and willingness, but in different ways. While capability factors affect a firm's foundation for patentable innovation capacities, willingness factors are stimulating factors that encourage or discourage patenting. This conceptual two-factor framework contributes to existing research on patenting propensities and extends our understanding of firm patenting behaviors.

In this study, we used information and communication technology (ICT) firms in Taiwan as sample firms and estimated models that capture the influence of determinants on firms' patenting behaviors. We conducted a questionnaire survey of 165 firms using count-data regression models to estimate firm innovation by using patent numbers. We respected the count-data nature of the patent number measure and estimated zero-inflated Poisson (ZIP) regression models, enabling us to examine determinants for two distinct types of firms: firms that always patent and firms that never patent. Moreover, we used the Poisson regression model to examine the validity of our conceptual two-factor framework in order to understand how capability and willingness factors affect firms' propensity to patent. The results are used to answer two research questions: whether firms that never patent differ from firms that always patent, and how capability and willingness factors affect firm patenting behaviors.

The remaining sections of this paper proceed as follows. Following the introduction, the second section reviews related literature and develops the research hypotheses. The third and fourth sections describe the research methodology and variable measurement, while the fifth and sixth sections present the results and discuss statistical findings, respectively. The final section concludes the paper.

Theoretical background

Patenting or not patenting

Patents offer a number of benefits. Mazzoleni and Nelson (1998), identifying four main benefits, stated that patents can: (1) motivate useful invention, (2) encourage required investment in commercialization, (3) award individuals, thus enhancing information disclosure, and (4) enable the orderly exploration of a broad prospect of technologies. Firms, particularly high-tech firms, normally use patents to protect their valuable inventions and to secure profits generated through the commercialization of such inventions (Nerkar and Shane, 2007). Graham and Sichelman (2008) summarized nine rationales for start-up firms to patent: (1) maintaining a supra-competitive price, (2) generating licensing revenues, (3) developing an arsenal for cross-licensing, (4) securing investments and financing, (5) using patents as shields, (6) engaging in patent bullying, (7) blocking and preemptive patenting, (8) substituting patents for non-disclosure agreements, and (9) validating an inventor's ideas. Given the benefits of patenting, firms are inclined to patent valuable inventions, which lead to a stream of studies investigating factors that affect a firm's patenting strategy, and the likelihood of receiving a grant award (Ernst, 1995; Granstrand, 1999; Guellec and van Pottelsberghe, 2000, 2002; Kortum and Lerner, 1999; van Zeebroeck and van Pottelsberghe, 2011). Their pioneering

work of Guellec and van Pottelsberghe (2000, 2002) found that Patent Cooperation Treaty (PCT) route, technological diversity, domestic and international R&D collaborations and/or co-applications, and the mix of designated states for protection (i.e., different countries where an invention is protected) (Guellec and van Pottelsberghe, 2000), increase the probability for patents to be granted. Moreover, Guellec and van Pottelsberghe (2002) also showed that geographical and technological specificities of patent filing strategies may influence the likelihood of receiving a grant award.

While prior studies have identified why firms choose to patent, we are more interested in investigating why firms never patent. One of the major reasons for firms choosing not to patent may simply be the higher cost of the legal work, particularly costs related to patent maintenance (Graevenitz et al., 2013; Grupp and Schmoch, 1999). Moreover, a firm may operate in a legal environment characterized by high patent imitation and high litigation costs (Graevenitz et al., 2013; Grupp and Schmoch, 1999). Alternatively, some firms may be in a low-differentiation environment (as may be the case for some contract manufacturing sectors), rendering innovation less attractive. As a result, firms have less incentive to patent. However, firms that never patent are not necessarily incapable of conducting innovation activities; therefore, there is a need to understand what attributes constitute innovation competence of firms that never patent. In other words, we attempt to explore determinants of innovation attributes that increase the possibility of firms choosing to patent or not to patent.

In referencing Herzberg's (1966) two-factor theory, this study attempts to extend our understanding of firms' patenting behaviors by differentiating capability factors (hygiene factors) and willingness factors (motivation factors). As shown in Fig. 1, rather than employing a traditional approach, which treats factors affecting patenting and not patenting in the same manner, the factors affecting the possibility of patenting should be treated separately from those affecting the possibility of not patenting. Under our framework, firms will patent only if they are able to eliminate or mitigate the influence of factors for not patenting, while simultaneously facilitating and enhancing the influence of factors for patenting. We thus recommend that firms develop patent-enabling factors such as capabilities while eliminating or mitigating patent-disabling factors such as unwillingness. Our framework offers further insight into determinants of patenting or not-patenting behaviors. In the following sections, we discuss factors that allow firms to enhance their capabilities and willingness factors that prevent firms from patenting.

Capability factors of patenting

A firm's innovation conduct (or strategy) is the central to nurturing innovation competence, which in turn leads to the development of new products and technologies. Prior studies offer a somewhat piecemeal list of factors that shape firm innovation competence, such as the capabilities of exploring technological opportunities (Tushman and Anderson, 1988), human capital (Michalisin et al., 1997; Nelson and Phelps, 1966), collaborative R&D projects (Caloghirou et al., 2004; Narula, 2004), R&D investments (Caloghirou et al., 2004; Sakakibara and Porter, 2001), core technology development or core business concentration (Miyazaki, 1995; Prahalad and Hamel, 1990), autonomous cultures

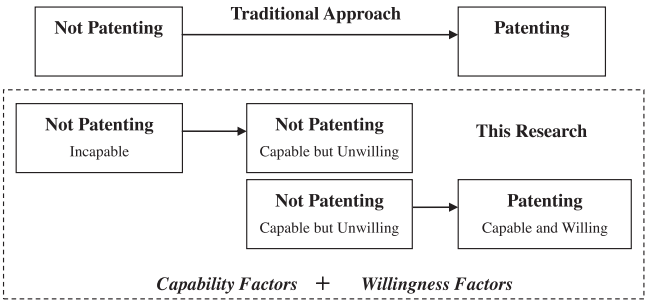

Fig. 1. Two-factor framework for patenting or not patenting.

(Amabile et al., 1996), and locating in a cluster (Krugman, 1991; Porter, 1998). Missing from this trawl through the literature is a focus on firm decisions not to patent. Firms that never patent are normally regarded as having no, or at least limited, intention to patent since firms would like to keep the innovation secret (Arora and Ceccagnoli, 2006) or to avoid higher costs of legal works for patenting, such as high patent maintenance fees (Graevenitz et al., 2013; Grupp and Schmoch, 1999). However, most of the aforementioned researchers have neglected to distinguish heterogeneous determinants between firm patenting and non-patenting decisions from the perspective of innovation competence. Thus, we attempt to distinguish between these two behaviors (patenting and not patenting) based on observed innovation competence, and particularly to investigate how firms can increase their possibility of patenting, while limiting their possibility of not patenting, based on these attributes of innovation competence.

As shown in Fig. 1 and as explained above, two factors affect firm patenting and non-patenting behaviors: capability and willingness. Capability factors are endogenous and linked to firms' internal attributes or resources, while willingness factors are exogenous and related to firms' external attributes or environments. Firms must first exhibit innovation capabilities that render them capable of patenting and then have willingness to patent. Thus, we first identify innovation capabilities that increase patenting propensity.

Firm size

Innovation projects demand substantial resources (Van de Ven, 1986). Moreover, innovation also implies uncertainty and risks (Eisenhardt and Martin, 2000). Thus, compared to small, resource-scarce firms, larger firms possess enough resources to absorb innovation failures. Furthermore, larger firms are more likely to offer experience with innovation projects that build organizational innovation capabilities (Majchrzak et al., 2004). Stronger innovation capabilities increase the likelihood of generating innovative outcomes. Thus, larger firms are expected to have a higher propensity to patent innovations due to their higher innovation capabilities. Prior studies also assert that firm size is positively associated with the number of patents (Scherer, 1965; Symth et al., 1975) or propensity to patent (Arundel and Kabla, 1998; Brouwer and Kleinknecht, 1999). As a result, this study expects that larger firms with more resources exhibit stronger innovation capabilities, thus increasing their propensity to patent.

Hypothesis 1. Larger firms with resource advantages will have a higher propensity to patent compared to smaller firms with resource disadvantages.

R&D efforts

While several prior studies (c.f. Xue et al. (2012)) treat R&D efforts measured by R&D intensity as a proxy of innovation, R&D efforts are actually inputs, rather than outcomes, of innovation. Thus, it is more accurate to treat R&D efforts as a determinant of innovation. Technological opportunities provide firms a competitive advantage in transforming their products and production processes during earlier stages of technological development (Tushman and Anderson, 1988). Firms' capabilities of exploring and exploiting new technological opportunities rely on their existing capabilities (Miyazaki, 1995). Thus, firms' R&D efforts can strengthen existing capacities to explore and exploit new technological opportunities. Thus, firms that devote more resources to R&D efforts are more capable of exploring and exploiting new technological opportunities (i.e., to innovate) and are then more likely to patent their inventions. Suzuki et al. (2006) also find that R&D expenses are positively associated with propensity to patent.

Hypothesis 2. Firms dedicating greater efforts to R&D will have a higher propensity to patent compared to firms dedicating little effort to R&D.

Core technology capability

A firm's core technologies may influence the trajectory and speed of innovation (Miyazaki, 1995). Firms exhibiting highly-concentrated and long-term involvement in core technologies will present

enhanced innovation capabilities (Huang, 2011), which in turn increases their possibility to patent their innovations. Moreover, technological improvements are continuously patented, and follow-up patents may be used to form a patent fence around core technologies (Gredel et al., 2012). As a result, firms exhibiting superior core technology capabilities are more likely to patent related technologies around their core technologies.

Hypothesis 3. Firms exhibiting superior core technology capabilities will have a higher propensity to patent compared to firms with fewer core technology capabilities.

Core business

Prahalad and Hamel (1990) proposed that a core business is composed of several core competencies, which in turn enhance the competitive advantage of a firm. According to Miyazaki's (1995) study, a firm's core business may influence the direction and speed of innovation. For instance, a firm characterized by a highly concentrated core business is more likely to utilize resources that serve as core competences of the core business, which potentially enhance innovation and thereby increase the likelihood of patenting innovative outcomes. Furthermore, if a firm's core business serves as its major field of interest, the firm may employ a regime of appropriability (e.g., patents or trade secrets) to protect the core business (Hagedoorn and Duysters, 2002). Thus, firms with a highly concentrated core business are more likely to patent.

Hypothesis 4. Firms with a highly concentrated core business will have a greater propensity to patent compared to firms with a less concentrated core business.

R&D human capital

Underutilized resources create managerial incentives for new capability creation (Penrose, 1959). The accumulation of new capabilities then affects means of responding to innovation opportunities (Teece et al., 1997). This suggests an important role played by human capital, and especially when it is deemed a scarce and valuable resource (Barney, 1991; Kogut and Zander, 1992). Building human capital requires that employees be offered intense, long-term training and learning experiences (Cohen and Levinthal, 1990; Michalisin et al., 1997), which prevents reliance on easy imitation or substitution in the short term (Reed and DeFillippi, 1990). Thus, attracting and possessing superior human capital can enhance innovation capabilities, which enables firms to become more innovative, and then increases propensity to patent. Scherer (1965) deemed R&D employment an important inventive input. Dedrick and Kraemer (1998) used the number of individuals holding scientific and technological degrees to assess a nation's innovativeness. Storey and Tether (1998) also asserted that supply of PhDs in science and technology affects innovation in technology-based firms. Therefore, we can hypothesize that firms with a higher proportion of scientists and engineers or employees with postgraduate degrees may present superior innovative capabilities, which in turn enhance their innovation outcomes and increase their possibility of patenting. Thus, we can derive the following hypotheses:

Hypothesis 5a. Firms employing a higher proportion of full-time scientists and engineers will have a higher propensity to patent compared to firms employing a lower proportion of full-time scientists and engineers.

Hypothesis 5b. Firms employing a higher proportion of employees with postgraduate degrees will have a higher propensity to patent compared to firms employing a lower proportion of employees with postgraduate degrees.

Autonomy of R&D

According to Amabile (1998), the key to improving creativity is to offer people autonomy with respect to processes, but not with respect to goals. As Amabile (1998) stated, 'Creativity thrives when managers let people decide how to climb a mountain; they needn't, however, let employees choose which one' (p. 81). Abbey and Dickson (1983) asserted that a firm's R&D personnel autonomy is highly

correlated with firm innovation. Ogbuehi and Bellas (1992) also argued that establishment of autonomous R&D entities within a decentralized structure helps firms compete in global new product development. Amabile et al. (1996) found that autonomy or freedom afforded to a firm's employees can enhance the firm's creativity. Thus, firms employing autonomous R&D environments are more capable of achieving a higher degree of innovativeness and creativity, which in turn increases the firm's propensity to patent and to protect innovative outcomes.

Hypothesis 6. Firms that allow for greater autonomy with respect to R&D activities will have a higher propensity to patent compared to firms that offer less autonomy.

Willingness factors of patenting

A shift in business strategies towards patenting strategies may be marked by either an increase in patent propensity rates (the percentage of innovations that are patented), or a more intensive exploitation of patents, or both. Granstrand (1999) used case studies and other data sources to argue that firms are exploiting their patents increasingly intensively, whereas Kortum and Lerner (1999) used patent statistics to show that an increase in patenting in the United States has more likely been due to an increase in the generation of patentable inventions than due to an increase in patenting propensities stimulated by legal environments. These results imply that capability factors to patent (generate patentable inventions) should be distinguished from willingness factors to patent (patent propensity rates), which further leads to an interesting question: why would a firm that is capable of patenting be unwilling to patent? In addition to the aforementioned capability factors, willingness factors may also affect firms' patenting strategy. According to prior works, the PCT route, technological diversity, R&D collaborations, as well the geographical and technological specificities may also influence the likelihood of filing new patents (Guellec and van Pottelsberghe, 2000, 2002), which in turn further influences firms' willingness to patent. Thus, following prior studies, this study employs technological specificities (i.e., product/process innovation and new-to-the-firm/new-to-the-world innovation), R&D collaborations (i.e., collaborations with universities, research institutions, competitors, or governments), and geographical specificities (i.e., cluster effect) as willingness factors to examine whether these attributes affect firms' patent propensity.

Process and product innovation

When a firm files a patent, it may need to disclose different types of information to competitors or imitators. Concerns regarding imitation and information disclosure may then reduce the firm's propensity to patent (Arundel and Kabla, 1998; Cohen et al., 2002). For instance, patenting a process innovation would disclose information that could be used by competitors in their manufacturing processes. Firms may avoid patenting process innovations due to difficulties related to detecting infringement (Arundel and Kabla, 1998). On the other hand, in preventing the reverse engineering of innovative products, firms are less likely to patent product innovations, and especially if secrecy serves as an important means of product innovation protection (Arundel and Kabla, 1998). Thus, we expect that both process and product innovation reduce propensity to patent in order to prevent imitation and information disclosure. However, in comparing the difference between propensities to patent process and production innovations, prior studies suggest that process innovations are generally less likely to be patented compared to product innovations (Arundel and Kabla, 1998; Brouwer and Kleinknecht, 1999). Patent appreciation is more likely to be employed to protect product innovations than process innovations (Brouwer and Kleinknecht, 1999). Based on the above discussion, we present the following hypotheses:

Hypothesis 7a. Firms that more emphasize process innovations will have a lower propensity to patent.

Hypothesis 7b. Firms that more emphasize product innovations will have a lower propensity to patent.

Hypothesis 7c. Firms that more emphasize process innovations will exhibit an even lower propensity to patent compared to firms that more emphasize product innovations.

New-to-the-firm and new-to-the-world innovations

Innovations can be divided into 'new-to-the-firm' innovations (i.e., those that are already known in the industry) and 'new-to-the-world' (i.e., those that have not yet been introduced by any competitor) (Laursen and Salter, 2006). While the former category is most likely to refer to imitative innovations, which may incorporate existing technologies or knowledge that has been patented, 'new-to-the sector-world' innovations may be interpreted as 'true' innovations, which may incorporate new technologies or knowledge that could be patentable (Brouwer and Kleinknecht, 1999). Thus, we expect that firms conducting adaptive and new-to-the-firm innovations may have a lower propensity to patent compared to those that develop new-to-the-world innovations.

Hypothesis 8. Firms that develop adaptive and new-to-the-firm innovations will exhibit a lower propensity to patent relative to firms that invest in new-to-the-world innovations.

External R&D collaborations

External R&D collaborations with universities and research institutions. External R&D collaboration is carried out to acquire essential technologies and involves the delivery of information from universities, research institutions, and government laboratories to firms (Parker and Zilberman, 1993). Several prior studies have focused on collaborations between universities and firms, and some scholars have suggested that firms that participate in R&D collaborations with universities exhibit stronger innovative outcomes, including spin-off success (Lockett et al., 2003), increased citations for firm patents (Zucker et al., 2002), and increased sales from new products (Belderbos et al., 2004), than those that do not. R&D collaborations can also be carried out with research institutions. Empirical studies suggest that firms engaging in collaborative R&D projects with research institutions exhibit stronger innovative outcomes (e.g., product innovation (Nieto and Santamaria, 2007)), which in turn increases the likelihood of patenting. In particular, innovations generated through collaborations with universities or research institutions are premised on basic research (Rosenberg and Nelson, 1994) that has yet been patented. Thus, firms conducting R&D collaborations with universities and research institutions are more likely to patent innovative outcomes. We thus derive the following hypotheses:

Hypothesis 9a. Firms that commit more to R&D collaborations with universities will exhibit a higher propensity to patent compared to firms that commit less to such collaborations.

Hypothesis 9b. Firms that commit more to R&D collaborations with research institutions will exhibit a higher propensity to patent compared to firms that commit less to such collaborations.

External R&D collaborations with competitors. Collaborations with direct competitors are difficult to manage (Hamel et al., 1989) and are more likely to spark learning races. Under such circumstances, firms attempt to extract as much knowledge as possible from partners, while divulging as little as possible (Hamel, 1991; Khanna et al., 1998; Wen and Chuang, 2010). Nooteboom (1999) asserted that such opportunities for free ridership, or for one party to gain more than others, will harm the collaboration. Therefore, when firms engage in collaborations with competitors, they will be more willing to employ appropriation regimes, such as patents, to protect their in-house innovations and commercialized benefits, and therefore prevent imitation from collaboration partners, particularly competitors. Thus, we can derive the following hypothesis.

Hypothesis 9c. Firms that commit more to R&D collaborations with competitors will exhibit a higher propensity to patent compared to firms that engage less in such collaborations.

External support from the government. In some cases, technology licensing or transfer may decrease internal R&D incentives. Firms that receive government subsidies are typically seeking ways to lower costs. Internal R&D expenses may diminish if the primary objective of external collaborations is to save costs (Sakakibara, 1997), and this leads to a crowding-out effect (Wallsten, 2000; Lach, 2002).

Thus, governmental subsidies displace internal R&D investments. Moreover, some government-funded R&D collaborations are regarded as less risk-seeking projects due to procurement agreements (Mowery, 1998), and incentives to innovate are lower because the outputs of collaborations are guaranteed to be sold back to governmental agencies. Third, some technologies transferred via government-funded R&D collaborations may have been already patented by governmental agencies, which also reduces the propensity to patent. Thus, R&D projects supported through public funding may have no substantial impact on firm innovation (Czarnitzki et al., 2007) due to crowding effects on internal R&D efforts, less incentive to innovate, and due to collaborations with patented technologies. This implies that fewer innovation outputs can be patented. Thus, we propose the following hypothesis:

Hypothesis 9d. Firms that receive more external support from the government will exhibit a lower propensity to patent compared to firms that receive less support from the government.

Cluster effect

Some scholars have suggested that clustering may generate competitive advantages with respect to innovation and productivity growth, as it enables firms to acquire industry-specific knowledge, well designed downstream and upstream networks, and opportunities to explore and exploit new technologies (Porter, 1990, 1998). Prior agglomeration studies have suggested that agglomeration phenomena or clusters can stimulate a firm's technology competence and innovation due to spillover effects (Best, 1999; Ganesan et al., 2005). Peer pressure effects reinforced by a higher concentration of competitors in a cluster also intensifies firm innovation (Beal and Gimeno, 2001; Porter, 2000). Thus, cluster effects play an important role in a firm's innovation. As a result, firms located in a cluster may benefit from such spillover effects or face peer pressure to innovate, and will then be more likely to innovate, which in turn increases the possibility of patenting to protect their value appropriation. Therefore:

Hypothesis 10. Firms located in a cluster will exhibit a higher propensity to patent compared to firms that are not located in a cluster.

An integrated two-factor patenting behavior framework

Firms are inclined to patent valuable inventions, which has inspired numerous studies on factors that affect firms' patenting strategies and on the likelihood of patent granting (Ernst, 1995; Granstrand, 1999; Kortum and Lerner, 1999; van Zeebroeck and van Pottelsberghe, 2011). Arundel and Kabla (1998) and Brouwer and Kleinknecht (1999), for instance, found that factors such as firm size, R&D collaborations, and sector differences have various impacts on a firm's propensity to patent. Guellec and van Pottelsberghe (2000, 2002) also found that factors such as the PCT route, technological diversity, R&D collaboration, the mix of designated states for protection, and the geographical and technological specificities (Guellec and van Pottelsberghe, 2000, 2002) affect the patent-grant likelihood. Although the results of these studies are fruitful, most of them investigate the effects of these potential factors on patent propensity separately, without using an integrated framework. However, factors affecting firms' decisions to patent or not should be further differentiated. Similar to Herzberg's (1966) two-factor theory, we attempt to divide factors of patent propensity into capability (hygiene) factors and willingness (motivation) factors. In our two-factor framework, we hypothesize that firms should develop their capabilities or capacities to increase their likelihood of patenting while eliminating or mitigating factors that discourage patenting. In other words, in addition to capability factors, willingness factors play an important role in firms' decisions to patent or not. While capability factors determine firms' potential with respect to innovation development, willingness factors affect intentions to patent developed innovations. Both factors thus affect firms' propensity to patent. Thus, in this study, we expect that while a greater presence of capability factors will increase firms' propensity to patent due to a higher likelihood to secure patentable innovations, willingness factors reinforce the positive effect of capability factors on propensity to patent. Thus:

Hypothesis 11. Firms' willingness to patent positively moderates the effect of capabilities on their propensity to patent.

Fig. 2 presents the research framework related to the aforementioned hypotheses.

Methods

We employed the count regression model to identify determinants of patent propensity among Taiwanese ICT firms. In most prior studies, Poisson regressions have been employed to examine a count-based dependent variable, such as the number of patents (Almeida and Phene, 2004; Keil et al., 2008). The Poisson regression model and its various modifications have been extensively applied to several contexts in social science studies, and particularly to those regarding innovation management. For instance, Hausman et al. (1984) employed the model to examine the relationship between patents and R&D expenditures. Nevertheless, these researchers do not differentiate between the effect of zero and non-zero observations on the dependent variables used in their studies. The classic Poisson regression model for count data is often of limited use to researchers in some disciplines because the empirical count data typically exhibit over-dispersion features and/or an excessive number of zeros. If there are many zero counts in the data, two states may be assumed to better reflect the situation. One of them is the structural zero (or zero count) state in which the only counts are zeros. The other is the sampling zero state in which the only counts are zeros. In order to overcome the limitation of Poisson regression, we used a technique that accounts for unobserved heterogeneity and deals appropriately with the excess zeros observed in the dependent variable. This estimation model, to our knowledge, has not been widely used to explain innovation outcomes in prior research, though it was employed in a study by Fontana et al. (2006). Fontana et al. (2006) used the zero-inflated negative binomial model to investigate factors affecting university–industry R&D projects. In our research, we use a similar technique, ZIP regression, to differentiate behaviors related to the observed innovation outcomes: a group of zero-patent firms (those that never patent) and a group that has recorded patents. The ZIP

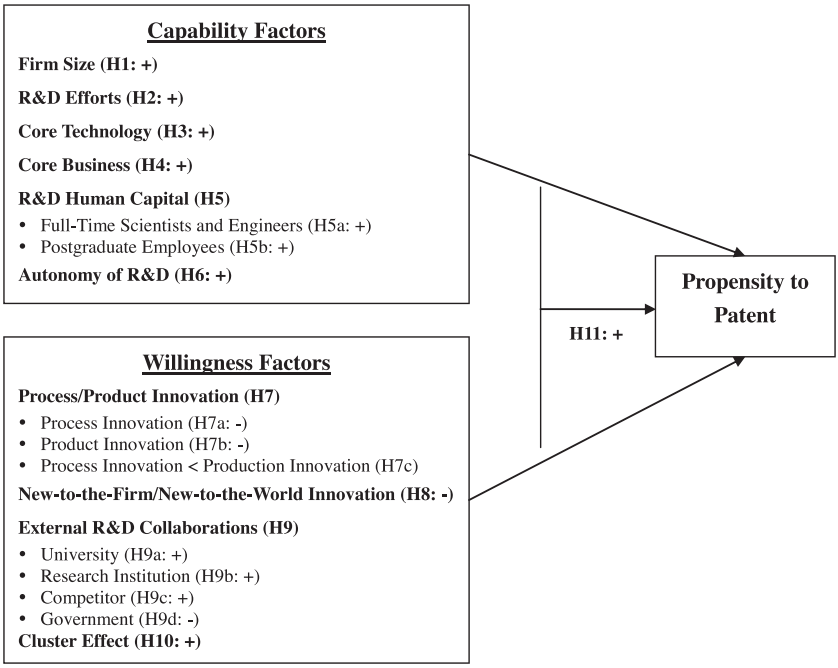

Fig. 2. Research framework.

regression model is a generalized linear model that provides a solution to the over-dispersion problem, and that may operate better when excess zeros are present. Numerous studies have examined potential uses of the ZIP model to fit count data and thus allow for the presence of too many zeros.[2] By differentiating firms that never patent from firms that always patent, firms can identify means of limiting patent-discouraging factors while promoting patent-encouraging factors. This study thus employs the ZIP regression model to examine whether firms that never patent exhibit different characteristics from those that patent. We then used the Poisson regression to examine models with the interaction term.

Samples and variable measurement

We drew up a list of sample firms for this study from the Taiwanese ICT manufacturing sector. Given the high market share of Taiwanese firms in the global ICT sector and the rapid growth of the ICT industry (Dedrick and Kraemer, 1998) during the survey period, the Taiwanese ICT industry became our first choice to investigate a firm's propensity to patent in such the context. Given differences between manufacturing and service firms, we excluded service firms from the sample. All firms included in the sample are listed on the Taiwanese Stock Exchange, and their headquarters are located in Taiwan. As the majority of Taiwanese ICT firms went public after the mid-1990s, we included firms with available data from the mid-1990s. Our initial sample included 415 potential firms, accounting for approximately 80% of the Taiwanese market share in 2002. A questionnaire survey was mailed to CEOs or senior managers of the sample firms. The two mail surveys were conducted in September 2002 and January 2003. We also conducted face-to-face interviews at three trade exhibitions related to the ICT industry in Taiwan between September 2002 and October 2002. Of the 415 firms targeted, 169 firms returned complete questionnaires. After excluding questionnaires with inappropriate responses or missing data, we obtained a valid sample of 165 firms, resulting in a 40% response rate for this study. We then conducted a one-way analysis of variance (ANOVA) test to examine differences among the three sub-samples in terms of sales. We found no significant difference among them ($p > 0.1$), suggesting that no inter-group sample bias was present.

The constructs employed in this research consist of a varying combination of quantifiable attributes. As some constructs (e.g., patents and R&D intensity) were easily quantified, we used readily available data from public sources, such as those of the Securities and Futures Institute (SFI) based in Taiwan. As other constructs (e.g., product and process innovation) cannot be quantified from official sources, in such cases we collected primary data through a structured questionnaire consisting of 12 items to assess the determinants of firm patenting behaviors. The respondents, who were mostly senior managers or CEOs, selected an answer from a series of statements standardized on a five-point Likert scale. The Cronbach's alpha of variables measured by the questionnaire ranged from 0.6 to 0.8, suggesting that our variables exhibited sufficient reliability (see Appendix 1).

Dependent variable

Following Almeida and Phene's (2004) measurement method, we used the number of patent applications to measure innovation performance. Considering the lag effect between innovation competence and outputs, we calculated the number of patents applied in Taiwan between 2003 and 2005. The firms studied here – that is, Taiwan's original equipment manufacturing (OEM) suppliers – mainly sell their products to multinational firms (Chen, 2005; Huang and Yu, 2012). While patents for product innovation are important in export markets, patents for process innovation are also important in production countries. Thus, patenting in Taiwan is especially critical to Taiwanese OEM suppliers, as it protects innovative production processes from competitor imitation.

[2] For an overview of count data models in econometrics, see Cameron and Trivedi (1998) as well as Long and Freese (2006). For information on other related issues, such as model selection, see McCullagh and Nelder (1989) and Cameron and Trivedi (1998).

Independent variables – capability and willingness factors

Based on the preceding literature review, the following constructs are central to measuring firms' capability and willingness factors with respect to patenting propensity.

Firm size

We measured firm size based on average employee numbers for the entire company between 1996 and 2002. The number of employees was obtained via the SFI database.

R&D efforts

Firm R&D efforts were measured by R&D intensity, which was calculated from R&D expenditures as a percentage of sales for the entire company from 1996 to 2002. R&D intensity was obtained from the SFI database.

Core technology

Zahra (1996) used three items to measure the extent of a firm's pioneering in its new-product innovation. Following Zahra's method, we measured core technology levels by asking respondents questions regarding the extent of a firm's new product development compared to that of its competitors. We assessed three items relating to this variable on a five-point Likert scale ranging from one (strongly disagree) to five (strongly agree).

Core business

Core business was measured by using the highest production value of a firm's product as an average percentage of sales between 1996 and 2002; these figures were obtained from the SFI database.

Human capital

Each firm's human capital was measured using two indicators: full-time employed scientists and engineers in the R&D department, and employees holding postgraduate degrees. Full-time employed scientists and engineers (FTSE) were measured by a percentage using the number of full-time employed scientists and engineers in the R&D department divided by total employees, while employees holding postgraduate degrees were measured by a percentage obtained via the number of employees holding postgraduate degrees divided by the total number of employees in the entire company. The full-time employed scientists and engineers in the R&D department and employees holding postgraduate degrees were obtained through our questionnaire survey.

Autonomy of R&D

Zain et al. (2002) measured a firm's sources of innovation by asking whether innovation decisions are made by top management teams. We revised their approach and measured the autonomy of the R&D workforce by asking respondents whether top management teams decide the direction of the firm's innovation with two items on a five-point Likert scale ranging from one (strongly disagree) to five (strongly agree).

Product and process innovation

Following Fritsch and Meschede's (2001) study, which evaluated the importance of firms' product and process innovation, we measured the importance of product and process innovation evaluated by the firms using a five-point Likert scale survey ranging from one (not important) to five (very important).

New-to-the-firm or new-to-the-world innovation

This construct was measured through the survey by asking respondents to evaluate whether firm innovations fall into the category of 'new-to-the-firm' (i.e., already known in the industry, score of one) or 'new-to-the-world' (i.e., not already introduced by a competitor, score of five) innovations.

External R&D collaborations

Our survey questions asked respondents to evaluate the extent to which they had committed to R&D collaborations with external partners, including universities, research institutions, and competitors (Lee et al., 2001), and the extent to which they had accepted licensed technologies or support from the government (Grupp, 1997). Similarly, these items were assessed on a five-point Likert scale ranging from one (few commitments/receiving little support) to five (many commitments/receiving more support).

Cluster effect

A dummy variable was employed to distinguish between the two groups by assigning firms a value of zero if they were not located in a cluster and of one if they were. A cluster is defined as a geographically proximate group of interconnected companies and associated institutions in a particular area, linked by commonalities and complementarities (Porter, 1998). Prior studies treat science parks as a type of clusters since science parks are surrounded by universities, research institutions, businesses and other supporting organizations (Tan, 2006; Yang et al., 2009), which are regarded as policy-driven clusters (Chiesa and Chiaroni, 2005). Thus, we used the Hsinchu Science Park (HSP) as a cluster to determine whether firms are located in a cluster.

Capability factors

The construct for capability factors was calculated by the predicted value of variables (firm size, R&D efforts, core technology, core business, human capital, and autonomy of R&D) via the Poisson regression model.

Willingness factors

The construct for willingness factors was calculated by the predicted value of variables (process innovation, product innovation, new-to-the-firm/new-to-the-world innovation, external R&D collaborations, and cluster effect) via the Poisson regression model.

Results

Descriptive statistics and correlations

Table 1 provides the descriptive statistics for the sample firms considered in this study. The table shows an average firm size (in terms of the total number of employees) of 1016. Full-time scientists and engineers comprise an average of 17% of all employees, while the average number of employees holding postgraduate degrees comprises 7% of the total employees. The average percentage of the firm's primary core business is 76.58%, suggesting that sampled firms focus heavily on core businesses. The average R&D intensity level (R&D expenditure as a percentage of sales) is 5.32%, which is lower than the average R&D intensity level (7.2%) for firms in the Organisation for Economic Co-operation and Development (OECD) countries (OECD, 2003). These results are consistent with the manufacturing orientation of Taiwanese firms, which are inclined to invest less in R&D activities (Dedrick and Kraemer, 1998; Lin, 1998).

Table 1 also shows correlation coefficients for all of the explanatory variables. Only a few explanatory variables present inter-correlations. However, tests for multicollinearity show that little multicollinearity exists among the independent variables since the values of the generalized variance inflation factor (VIF) (Fox and Monette, 1992) are less than 3.4 under Poisson regression models. The estimation results do not differ significantly in terms of the signs and magnitudes of the estimates when both or one of the variables are retained in the model fitting.

ZIP regression results

We used the Taiwan patent dataset as the dependent variable for the Poisson regression model. Table 2 shows results related to patenting in Taiwan. The 'count model' shown in Table 2 indicates the estimates for the mean function of ZIP models, while 'always zero' denotes the estimates of

Table 1
Descriptive statistics and correlations.

	M	SD	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) Patent	26.08	83.22	1.00														
(2) Firm size (employee)	1016	1687	0.39**	1.00													
(3) R&D efforts	5.33	8.06	−0.01	−0.12	1.00												
(4) Core technology	2.77	0.99	0.13	0.11	−0.06	1.00											
(5) Core business	76.58	22.25	0.05	0.03	−0.03	0.11	1.00										
(6) FTSE	0.17	0.18	0.08	−0.28**	0.46**	−0.12	−0.15*	1.00									
(7) Postgraduate employees	0.07	0.10	0.13	−0.06	0.29**	−0.12	−0.04	0.58**	1.00								
(8) Autonomy of R&D	2.91	0.85	0.19*	0.12	−0.01	0.10	−0.16*	0.09	0.07	1.00							
(9) Process innovation	4.54	0.71	0.01	0.02	0.05	0.11	0.01	0.15	0.05	−0.05	1.00						
(10) Product innovation	4.38	0.78	0.03	0.11	−0.09	0.03	0.10	−0.04	0.05	−0.01	0.56**	1.00					
(11) New-to-the-world	2.96	1.16	0.09	0.03	−0.01	0.71**	0.02	−0.07	−0.06	0.18*	−0.01	−0.09	1.00				
(12) Universities	2.53	1.81	0.11	0.13	0.22**	−0.03	−0.09	0.19*	0.16*	0.03	0.14	0.20**	0.01	1.00			
(13) Institutions	2.31	1.95	0.03	0.12	0.15	0.04	0.03	0.15	0.09	0.03	0.15	0.12	0.05	0.59**	1.00		
(14) Competitors	2.30	1.93	0.14	0.17*	0.05	−0.12	−0.09	0.11	0.16*	0.06	0.03	0.12	−0.03	0.35**	0.44**	1.00	
(15) Government	1.31	0.57	0.03	0.18*	0.08	−0.11	−0.02	0.03	0.00	−0.06	0.09	0.07	−0.15	0.40**	0.35**	0.10	1.00
(16) Cluster effect	0.17	0.38	0.13	0.02	0.31**	−0.24**	−0.02	0.28**	0.48**	−0.10	0.04	0.01	−0.18*	0.16*	0.02	0.11	0.15

Table 2
ZIP estimation results – factors that affect patenting.

Variables	Always zero	$N=52$		Count model	$N=113$	
	γ	p-value	$e\gamma$	β	p-value	$e\beta$
Firm size	−0.00039*	0.050	0.9996	0.00032**	0.000	1.0003
R&D efforts	−0.02354	0.502	0.9767	−0.04465**	0.000	0.9563
Core technology	0.33959	0.230	1.4044	0.85355**	0.000	2.3480
Core business	−0.00414	0.624	0.9959	0.01351**	0.000	1.0136
FTSE	−1.02530	0.520	0.3587	3.05370**	0.000	21.1936
Postgraduate employees	0.16456	0.954	1.1789	−0.14903	0.435	0.8615
Autonomy of R&D	−0.09498	0.687	0.9094	0.51585**	0.000	1.6751
Process innovation	−0.44774	0.158	0.6391	−0.29870**	0.000	0.7418
Product innovation	−0.23160	0.436	0.7933	−0.24286**	0.000	0.7844
New-to-the-firm/New-to-the-world innovation	−0.35004	0.145	0.7047	−0.42893**	0.000	0.6512
External R&D collaborations – universities	−0.24346*	0.087	0.7839	0.11347**	0.000	1.1202
External R&D collaborations – institutions	−0.06473	0.643	0.9373	−0.10579**	0.000	0.8996
External R&D collaborations – competitors	0.19035	0.104	1.2097	0.13793**	0.000	1.1479
External R&D collaborations – government	0.46637	0.217	1.5942	−0.42349**	0.000	0.6548
Cluster effect	−0.05520	0.931	0.9463	0.59594**	0.000	1.8147
Sample size	165					
Log-likelihood	−2789.463					
Vuong Statistic	3.56**	0.000				
McFadden's R^2:						

Significance level: **5%; *10%.

parameters for the group of zero-patent firms. The Vuong statistic (Vuong, 1998) is used to test ZIP against Poisson regression models. The significant values of the Vuong statistic conclude that ZIP performs better than the Poisson model (also see the discussion in Appendix 2). Thus, zero-inflation effects occur when the Poisson regression is applied to this dataset. While the zero inflated negative binomial (ZINB) regression model was also applied to the data, a convergence of resulting estimates was not obtained. We thus did not discuss the ZINB in this paper.

A positive estimated value of the β coefficient for explanatory variables in the ZIP model indicates that an increase in a relevant variable leads to a higher expected count of patents, ceteris paribus. On the other hand, a negative value of γ indicates that a relevant variable reduces the log odds ratio of a non-patent. For example, the estimated coefficient for *cluster effect* is 0.59594, which indicates that, if other factors remain fixed, firms that belong to a cluster on average obtain 1.8147 times [exp(0.59594) = 1.8704] as many patents as those that do not belong to a cluster.

Among firms that always patent, larger firms exhibit a higher propensity to patent ($\hat{\beta} = 0.00032$, $p < 0.05$), which supports Hypothesis 1. Firms with higher R&D efforts present a lower propensity to patent ($\hat{\beta} = -0.04465$, $p < 0.05$). While firm size has positive effects on firms' propensity to patent, R&D efforts have a negative effect in this regard, which is contradicting Hypothesis 2.

Firms with higher concentrations on core technologies and core businesses exhibit a higher propensity to patent ($\hat{\beta} = 0.85355$, $p < 0.05$, and $\hat{\beta} = 0.01535$, $p < 0.05$, respectively), which support both Hypotheses 3 and 4. While firms employing a higher proportion of full-time scientists and engineers exhibit a higher propensity to patent ($\hat{\beta} = 3.05370$, $p < 0.05$), the presence of more postgraduate employees has no effect on propensity to patent ($\hat{\beta} = -0.14903$, $p > 0.1$), suggesting that Hypothesis 5a is supported but Hypothesis 5b is not supported. Moreover, firms that afford R&D departments high levels of autonomy exhibit a higher propensity to patent ($\hat{\beta} = 0.51585$, $p < 0.05$) than firms that allow less autonomy, which supports Hypothesis 6. On the contrary, firms with process innovations, product innovations, and new-to-the-world innovations exhibit a lower propensity to

patent ($\hat{\beta} = -0.29870$, $p < 0.05$, $\hat{\beta} = -0.24286$, $p < 0.05$, and $\hat{\beta} = -0.42893$, $p < 0.05$, respectively), which supports Hypotheses 7a and 7b, but contradicts Hypothesis 8. As the coefficient for process innovation is even smaller than that of product innovation ($-0.29870 < -0.24286$), this implies that firms focusing on process innovations rather than on product innovations will have a lower propensity to patent, which supports Hypothesis 7c. Regarding external R&D collaborations, firms that commit to collaborations with universities and competitors exhibit a higher propensity to patent ($\hat{\beta} = 0.11347$, $p < 0.05$ and $\hat{\beta} = 0.13793$, $p < 0.05$, respectively) compared to those that do not commit to such collaborations. However, firms engaged in external collaborations with research institutions and receiving licensed technologies or government support exhibit a lower propensity to patent ($\hat{\beta} = -0.10579$, $p < 0.05$ and $\hat{\beta} = -0.42349$, $p < 0.05$, respectively). These results support Hypotheses 9a, 9c and 9d, but contradict Hypothesis 9b. With respect to the cluster effect, firms located in science parks exhibit a higher propensity to patent ($\hat{\beta} = 0.59594$, $p < 0.05$). Thus, Hypothesis 10 is supported.

Regarding firms that never patent, as shown in Table 2, while larger firms exhibit a lower probability of not patenting ($\hat{\gamma} = -0.00039$, $p < 0.10$), firms engaged in R&D collaborations with universities also present a lower probability of not patenting ($\hat{\gamma} = -0.24346$, $p < 0.10$).

Moderation results

In this research, we used the Poisson regression model to examine moderation effects of willingness factors by capability factors on propensity to patent. In a Poisson regression, model goodness of fit is typically evaluated by deviance and Akaike's Information Criterion (AIC). The above listed information criteria are in small-is-better form. As shown in Table 3, the AIC of Model 4 decreases compared to those of Models 1, 2, and 3. Similarly, the decreasing AIC in Model 4 suggests that interaction effects of willingness factors by capability factors have an impact on firms' propensity to patent. Table 3 presents the estimation results for Models 1, 2, 3, and 4. Model 1 predicts that firms with a higher level of capability-only factors have a higher propensity to patent ($b = 0.009$, $p < 0.01$). Model 2 finds that firms with a higher level of willingness-only factors have a higher propensity to patent ($b = 0.018$, $p < 0.01$). The third model includes willingness factors into the estimation for the effect of capability factors on propensity to patent. The extent of willingness factors is found to have no significant effect on the propensity to patent ($p > 0.1$) after being added to the estimated regression (shown as Model 3). To further examine moderating effects of willingness factors by capability factors, this study used a regression model with interaction terms (shown as Model 4). As predicted, the higher extent of willingness factors can further enhance the positive association between capability factors and propensity to patent ($b = 0.001$, $p < 0.05$). Thus, Hypothesis 11 is also supported.

Table 3
Interaction effects of capability factors by willingness factors on propensity to patent (Poisson regression).

Exogenous variables	Model 1	Model 2	Model 3	Model 4
Predictor variables				
Capability factors	0.009***		0.008***	0.017***
	(28.325)[a]		(15.156)	(10.502)
Willingness factors		0.018***	0.006	0.016***
		(13.411)	(0.951)	(9.110)
Interaction models				
Capability factors × Willingness factors				0.001**
				(4.026)
Goodness of Fit[a]				
Log Likelihood	−5582	−6710	−5539	−5104
Deviance	10,703	12,957	10,616	9747
AIC	11,169	13,424	11,085	10,217

Significance level: ***1%; **5%; *10%.
[a] Wald Chi-Square.

Discussion

Firms that always patent versus firms that never patent

Our ZIP regression results answer the first research question, which sought to identify different factors that affect a firm's decision to patent or not. Most previous researchers have explored firm characteristics that affect propensity to patent, but without distinguishing firms that always patent from firms that never patent. Our results show that it is necessary for researchers to examine the difference between these two behavior groups of firms. The majority of factors, including capability and willingness factors, affect firms' propensity to patent among firms that always patent.

As shown in Table 2, for the group of firms that always patent, most capability factors have positive impacts on their propensity to patent. This is consistent with prior studies and supports our hypotheses. For instance, larger firms exhibit a higher propensity to patent innovations (H1), since they possess more resources (Van de Ven, 1986) and experience (Majchrzak et al., 2004) to enhance organizational innovation capabilities and to absorb innovation failures caused by uncertainty and risks (Eisenhardt and Martin, 2000). Moreover, technological improvements and follow-up innovations may be developed around core businesses and then are used to create a patent fence around core technologies (Gredel et al., 2012). As a result, if a firm has a high concentration on its core business (H4) and commits significant resources to advance core technologies (H3), it will present a higher propensity to patent. Firms employing a higher proportion of full-time scientists or engineers (H5a) and allowing significant autonomous decision-making in R&D departments (H6) may exhibit stronger research capacities while also encouraging innovative and creative activities (Abbey and Dickson, 1983; Amabile et al., 1996), which in turn increases their propensity to patent as a result of heightened innovative outcomes. However, R&D efforts have a negative impact on firms' propensity to patent, which is contrary to traditional wisdom. This negative relationship may be explained by the fact that if a firm's technological strategy is oriented towards existing technologies (i.e., investing a large proportion of the R&D budget into existing technologies which are less new to the world), the firm will be less likely to appropriate new innovations in patent form (Beneito, 2006). Thus, it may be suggested that our sample firms in Taiwan, even for those firms which invest more on R&D activities than other firms, mainly focus on improving their existing technologies via R&D investments, limiting propensity to patent new technologies.

Concerning willingness factors, as expected, both process and product innovations result in a lower propensity to patent, while product innovation encourage a higher propensity to patent compared to process innovation. This may be attributable to the fact that imitation threats (Hu, 2010) and information disclosure requirements (Arundel and Kabla, 1998; Cohen et al., 2002) may prevent firms from patenting. Firms are less likely to patent if such process or product innovations are important to their competence. Furthermore, since process innovations may not create as much value as product innovations, the appreciation of patents as a means of process innovation protection is relatively less common than it is in the case of product innovation (Brouwer and Kleinknecht, 1999). This study reveals interesting findings concerning the negative effect of new-to-the-world innovations on firms' propensity to patent. A possible explanation for this is that 'new-to-the-firm' innovations, which are more likely to be incremental innovations, are developed based on existing technologies and knowledge. Firms can more easily develop new-to-the-firm innovations and patent these in order to form a patent fence (Gredel et al., 2012) around existing technologies. On the contrary, 'new-to-the-world' innovations are more likely to be radical, as such new inventions have not yet been previously developed by competitors. Although patenting may offer institutional regimes to protect new-to-the-world innovations from imitation, it may also increase knowledge leakage risks (Falvey et al., 2006). Leakage risk concerns may reduce firms' incentive to patent new-to-the-world innovations. Thus, we find that firms engaged in adaptive and new-to-the-firm innovations may present a higher willingness to patent compared to those firms that engage in new-to-the-world innovations. Regarding external R&D collaborations, firms that participate more in external collaborations with universities and competitors will exhibit a higher propensity to patent, whereas firms that collaborate with research institutions and receive licensed technologies or government support will present a lower propensity to patent. Firms are inclined to patent innovations that are outcomes of collaborations with

universities because these collaborative outcomes are most likely oriented towards basic science (Rosenberg and Nelson, 1994), and academia requires that they be patented. Moreover, firms are inclined to patent their own innovation outcomes when collaborating with competitors in order to prevent others from imitations (Cohen et al., 2000, 2002; Kingston, 2001; Levin et al., 1987). On the other hand, our findings suggest that firms are less likely to patent their innovation outcomes after collaborating with research institutions or receiving licensed or transferred technologies from the government. This may be attributable to the fact that most collaborations with research institutions in Taiwan involve transferring patented technologies or knowledge from research institutions (most of which publicly owned) to firms (Chang, 2003). Such firms thus exhibit less need to patent new innovations, as they enjoy greater access to external resources at lower costs. A similar rationale applies for firms receiving licensed or transferred technologies from the government. With respect to the cluster effect, our findings suggest that firms located in a science park exhibit a higher propensity to patent, since spillover effects (Best, 1999; Ganesan et al., 2005) and peer pressures (Beal and Gimeno, 2001; Porter, 2000) in the cluster stimulate firms' technology competence and broaden access to patentable innovations.

Regarding firms that never patent, we found that larger firms and firms that exhibit strong commitment to R&D collaborations with universities have a lower propensity of non-patenting behaviors. Most other factors, including both capability and willingness factors, are found to have no impact on the possibility of not patenting. Our findings show that most factors can only increase firms' propensity to patent, but do not reduce their possibility of not patenting. This finding is particularly pivotal to firms that never patent, since it highlights means of limiting non-patenting behaviors. The results also suggest that some factors, such as larger firm size and R&D collaborations with universities, not only enhance the propensity to 'patent', but also reduce the possibility of 'not patenting'. The results confirm our research inquiry that different determinants affect patenting behaviors between firms that always patent and firms that never patent.

The effect of capability and willingness factors on propensity to patent

In examining the integrated two-factor framework, we used Poisson regression models with an interaction term. The results of Model 3 shown in Table 3 show that a greater extent of capability factors will lead to a higher propensity to patent, whereas the extent of willingness factors has no direct effect on propensity to patent.[3] More importantly, willingness factors positively moderate the relationship between capability factors and propensity to patent. To interpret moderation effects, we further divided the sample firms into two groups: higher and lower levels of willingness factors. Fig. 3 presents a graph of the interaction effects between these variables. Capability factors are positively associated with propensity to patent for both higher and lower levels of willingness factors. However, a higher level of willingness factors can further enhance the positive relationship between capability factors and propensity to patent. These results support our conceptual argument that determinants of propensity to patent should be divided into capability factors and willingness factors. While capability factors are direct determinants of propensity to patent, willingness factors play a partial moderating role in this regard. Firms should differentiate the impacts of capability and willingness factors on propensity to patent. Moreover, firms should attempt to strengthen their capability factors to enhance their capacity for innovation competence, which in turn leads to higher propensity to patent their innovative outputs. On the other hand, willingness factors should be appropriately considered as a means of facilitating motivations to patent.

To further elaborate interaction effects of individual capability and willingness factors on propensity to patent, we further considered moderation effects of each willingness factor on the relationship between capability factors and propensity to patent. Table 4 summarizes the results of the interaction effect results for each willingness factor. As shown in the results, among the

[3] While we tested capability and willingness factors separately, both factors were positively associated with propensity to patent (shown as Models 1 and 2 in Table 3). However, as we tested capability and willingness factors in the same model, we found that capability factors have positive impacts on propensity to patent, whereas willingness factors have no direct effect on propensity to patent. This suggests that capability factor effects on patenting propensities override effects of willingness factors.

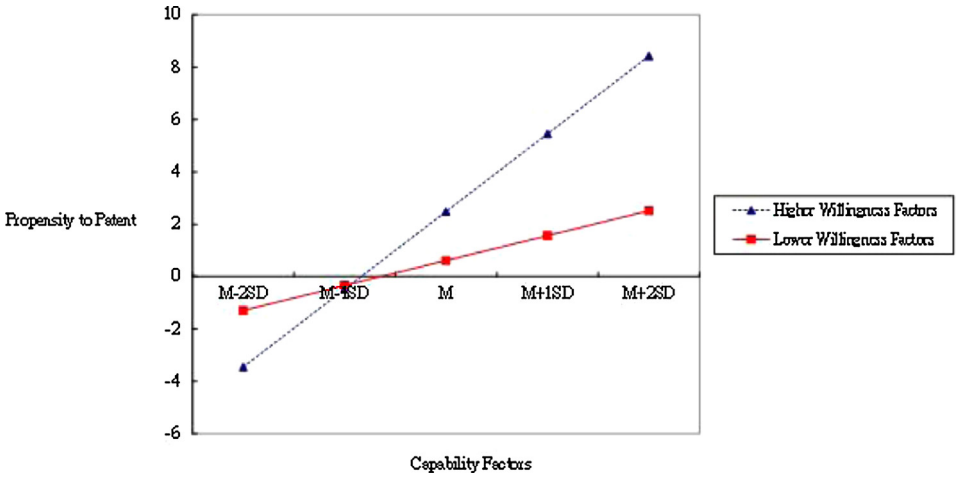

Fig. 3. Interaction effect of capability factors by willingness factors.

willingness factors, new-to-the-world innovations and cluster effects are found to have no moderating effect on the relationship between capability factors and propensity to patent, while process innovations, production innovations, and R&D collaborations with universities, research institutions, competitors, and the government are found to have moderating effects on relationships between certain capability factors and propensity to patent. We elaborate the individual interaction effects in detail in the following discussion section.

First, we found that a relationship between firm size and propensity to patent is negatively moderated by product innovation ($\beta=-0.330$, $p<0.01$) and R&D collaborations with research institutions ($\beta=-0.231$, $p<0.05$). This negative interaction effect implies that a greater extent of product innovation (or R&D collaborations with research institutions) will lead to a lower propensity to patent with increased firm size. Second, the relationship between R&D efforts and propensity to patent is negatively moderated by R&D collaborations with universities ($\beta=-1.189$, $p<0.1$). This result suggests that a greater commitment on R&D collaborations with universities will lead to a lower propensity to patent with increased R&D efforts. Third, the relationship between core technology and propensity to patent is negatively moderated by product innovations ($\beta=-0.408$, $p<0.05$). Similarly, this also implies that a stronger emphasis on product innovation will result in a lower propensity to patent when core technology development is prioritized. Fourth, the relationship between core business and propensity to patent is positively moderated by R&D collaborations with universities ($\beta=0.438$, $p<0.05$), research institutions ($\beta=0.340$, $p<0.05$), and competitors ($\beta=0.352$, $p<0.05$). These positive interaction effects refer to the fact that a greater commitment to R&D collaborations with universities, research institutions, or competitors will increase propensity to patent when a core business is highly focused. Fifth, the relationship between the percentage of full-time scientists or engineers and propensity to patent is positively moderated by R&D collaborations with universities ($\beta=0.718$, $p<0.05$). This suggests that a greater commitment to R&D collaborations with universities will also increase propensity to patent with increased percentage of full-time scientists and engineers. Moreover, the relationship between employees with postgraduate degrees and propensity to patent is negatively moderated by process innovations ($\beta=-0.650$, $p<0.05$), as well as R&D collaborations with universities ($\beta=-0.345$, $p<0.01$), research institutions ($\beta=-0.328$, $p<0.05$), and competitors ($\beta=-0.207$, $p<0.1$). This implies that a greater commitment to R&D collaborations with universities, research institutions, and competitors will decrease propensity to patent with increased proportion of employees with postgraduate degrees. Finally, the relationship between autonomy of R&D and propensity to patent is positively moderated by product innovations

Table 4
Interaction effects of capability factors and willingness factors on propensity to patent (individual variables).

β coefficient	Moderator (M) – willingness factors							
	Process innovation	Product innovation	New-to-the-world innovation	Universities	Institutions	Competitors	Government	Cluster effect
Capability factors								
Firm size	0.541***	0.687***	0.615***	0.648***	0.621***	0.639***	0.645***	0.545***
R&D efforts	−0.327	−0.602	−0.125	0.341	−0.012	−0.215	−0.240	−0.396
Core technology	0.441**	0.404**	0.488	0.247	0.472***	0.389**	0.365	0.517**
Core business	0.107	0.081	0.278	0.077	0.041	0.213	0.346	0.102
FTSE	0.424**	0.652***	0.423	0.219	0.470***	0.584***	0.697***	0.727***
Postgraduate employees	0.397**	0.184	0.226	0.213	0.126	0.252	0.087	−0.332
Autonomy of R&D	0.364**	0.213	0.390*	0.345*	0.357**	0.358**	0.392***	0.421**
Willingness factors								
Moderator (M)	0.275	0.014	−0.075	−0.161	0.002	0.086	−0.285	0.302
Interaction								
Firm size × (M)	−0.093	−0.330**	−0.084	−0.103	−0.231***	0.046	0.132	0.012
R&D efforts × (M)	−0.001	−0.086	−0.446	−1.189*	−0.378	−0.087	−0.056	0.165
Core technology × (M)	0.087	0.241	−0.056	0.063	−0.038	0.210	−0.408**	−0.212
Core business × (M)	0.146	0.135	−0.022	0.438**	0.340**	0.352**	0.270	0.116
FTSE × (M)	0.278	−0.120	0.270	0.718**	0.160	0.108	0.258	−0.235
Postgraduate employees × (M)	−0.650**	−0.195	−0.020	−0.345***	−0.328**	−0.207*	−0.057	0.231
Autonomy of R&D × (M)	0.195	0.413**	0.104	0.259	0.357**	−0.057	−0.152	−0.150
Goodness of Fit								
Log likelihood	−3616.088	−3630.442	−3979.366	−3563.148	−3471.224	−3818.853	7339.430	−3737.639
Deviance	6769.899	6798. 607	7496.454	6664.019	6480.170	7175.429	7339.430	7013.001
AIC	7264.176	7292.885	7990.731	7158.297	6974.448	7669.706	7833.707	7507.279

Significant level: ***1%; **5%; *10%.

(β=0.413, $p<0.05$) and R&D collaborations with research institutions (β=0.357, $p<0.05$). This means that a higher extent of product innovation (or R&D collaborations with research institutions) will increase propensity to patent when R&D departments are autonomous. These various interaction results provide insight to researchers regarding the fact that various capability factors interacted with certain types of willingness factors will affect firms' propensity to patent.

Conclusion

One of the most consistent findings noted in the literature on patenting behaviors is the relationship between determinants of patenting and firms' propensity to patent. However, only a small fraction of firms studied in this research displayed patenting behaviors. Nevertheless, the assumption that all firms that do not apply for patents are simply not adopting innovative strategies may be misleading. The main contribution of our research is to differentiate the behaviors of two heterogeneous groups: firms that never patent and firms that always patent. Our study shows that ZIP regression models may serve as a suitable explanatory tool for differentiating characteristics between these two forms of patenting behaviors.

More importantly, the results shed some light on our understanding that firms' patenting behaviors can be categorized into two types of determinants: capability and willingness factors. By developing a conceptual two-factor framework, our results suggest that while capability factors have direct impacts on firms' propensity to patent, willingness factors have a partial moderating effect on the relationship between capability factors and propensity to patent. Various individual interaction effects between capability factors and willingness factors on propensity to patent have been further identified and examined in this research. These findings enrich our understanding of how determinants interactively affect firms' patenting behaviors. Our two-factor framework extends knowledge regarding determinants of propensity to patent, which have not yet been fully investigated in prior studies.

Our research also has implications for business practitioners and policy makers. First, firms need to identify appropriate technological strategies that meet unique patenting needs. For firms that always patent, most determinants of capability factors, such as firm size, core technology, core business, R&D human capital in terms of full-time scientists and engineers, and creativity of organizational climate (autonomy of R&D), are found to increase a firm's propensity to patent in Taiwan. On the other hand, some willingness factors, such as R&D collaborations with universities and competitors or cluster effect, will increase a firm's propensity to patent, while other factors, such as process innovations, product innovations, new-to-the-world innovations, and R&D collaborations with research institutions and the government, will decrease propensity to patent. Our findings thus highlight determinants of patenting behaviors. From this research, business practitioners can identify circumstances that allow firms to foster in-house innovation and increase propensity to patent. Policy makers are also advised that R&D collaborations with public research institutions, as well as technology licensing or support from the government, may hinder in-house innovation, and thus limiting propensities to patent. Policy makers have to re-examine mechanisms of public support and their relationships with in-house innovation in Taiwan.

This study presents a number of limitations. First, we only considered patenting as an activity related to innovation. However, examining patenting in correlation with determinants of firms' innovation may not be universally applicable, since some inventions may not be patentable, or patenting them may be undesirable. Future studies should consider different types of innovation activities and measure non-patentable inventions in order to avoid potential bias effects. Moreover, since determinants that affect a firm's propensity to patent vary, the constructs we selected in this study only account for a portion of variables. Researchers may investigate other attributes, such as sector and geographical differences, in future studies.

Appendix 1. Measures – questionnaire items

Variables	Items	Cronbach's alpha
Autonomy of R&D	– Management approves appropriate resources (reverse scaled) – The final decision on adoption is made by top management (reverse scaled) (Zain et al., 2002)	0.60
Core technology	– Your firm is usually among the first to introduce new products to the market – Your firm is this industry's leader in introducing new products – Your firm is well known for introducing breakthrough-type products (Zahra, 1996)	0.69
Process innovation	– Please evaluate the importance of the following items in your enterprise's innovation: 1. Process innovation (Revised from Fritsch and Meschede, 2001)	Single item measurement
Product innovation	– Please evaluate the importance of the following items in your enterprise's innovation: 1. Product innovation (Revised from Fritsch and Meschede, 2001)	Single item measurement
New-to-the-firm/new-to-the-world innovation	– Please rate whether your firm's innovations are more new-to-the-firm- or new-to-the-world-oriented.	Single item measurement
External R&D collaborations (during the period of 1996 and 2002)	– Commitments to joint projects with universities (Lee et al., 2001) – Commitments to joint projects with research institutions (Lee et al., 2001) – Commitments to joint projects with competitors (Lee et al., 2001) – Receiving licensed or transferred technologies from the governmental sector (Grupp, 1997)	Single item measurement

Appendix 2. Poisson regression and ZIP results

Another important objective of our research was to empirically investigate the difference between Poisson and ZIP regression models. Appendix 2 provides a further comparison of these two methods. It shows that most results are similar between the Poisson and ZIP models (except with respect to the number of postgraduate employees). However, as mentioned earlier, the ZIP model provides a more detailed estimation of firms' propensity to patent by differentiating firms that always patent and the firms that never patent. Thus, it is necessary for researchers to employ the ZIP regression model to contribute to understanding on firms' patent behaviors.

Variables	Poisson		ZIP	
	β	p-value	β	p-value
Firm size	0.00035**	0.000	0.00032**	0.000
R&D efforts	−0.04223**	0.000	−0.04465**	0.000
Core technology	0.78731**	0.000	0.85355**	0.000
Core business	0.01288**	0.000	0.01351**	0.000
FTSE	2.87186**	0.000	3.05370**	0.000
Postgraduate employees	−0.89436**	0.000	−0.014903	0.435
Autonomy of R&D	0.54662**	0.000	0.51585**	0.000
Process innovation	−0.15077**	0.000	−0.29870**	0.000
Product innovation	−0.12552**		−0.24286**	0.000
New-to-the-firm/New-to-the-world innovation	−0.30576**	0.000	−0.42893**	0.000
External R&D collaboration – universities	0.16557**	0.000	0.11347**	0.000
External R&D collaboration – institutions	−0.10461**	0.000	−0.10579**	0.000

Appendix 2 (*Continued*)

Variables	Poisson		ZIP	
	β	p-value	β	p-value
External R&D collaboration – competitors	0.12698**	0.000	0.13793**	0.000
External R&D collaboration – government	−0.60528**	0.000	−0.42349**	0.000
Cluster effect	1.01844**	0.000	0.59594**	0.000
Sample size	165		165	
Log-likelihood	−3777.54		−2789.463	
Pseudo R^2/McFadden's R^2	0.496			

Significance level: **5%; *10%.

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