Firm Size and Characteristics of Innovations in the Markets for Technology

by

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A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Applied Science
in
Management Sciences

Waterloo, Ontario, Canada, 2009

AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

This paper investigates how the size of a firm affects its licensing strategy for patented technologies through empirical analysis of the characteristics at the technological, firm, and industry levels. Only firms with commercialization capabilities are considered in this study in order to compare the incentives of utilizing technologies internally with the incentives of selling them for licensing revenue. Focusing on licensing motivated by non-strategic purposes, empirical analysis shows that large companies are less willing to license patents that fit into their business focus, as well as those which have a low technological value in general. On the other hand, small firms are more inclined to license patents which are more relevant to their business focus, but less innovative on average. This study also finds that market share and competition intensity are important factors in their licensing decisions: the more competitive and the smaller the market share of the patents owned by large firms, the higher the chance that firms will list them on the market. In line with the revenue versus competition framework by Arora and Fosfuri (2003), this paper concludes that large firms are generally more concerned about the rent dissipation effect over the revenue effect from licensing, while the opposite is true for smaller firms.

Acknowledgements

I am deeply indebted to my supervisor, Dr. Bonwoo Koo, for his patience, understanding, and guidance throughout the whole research process. I would also like to express my gratitude to my family, especially my mother, for their continuing support.

In addition, I would like to convey thanks to Professor Cozzarin and Professor Onay for their valuable comments.

Lastly, I would like to thank Marin Kiefel, Steven Bahun, and Yan Dong for their technical support in writing the script.

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Chapter 1
Introduction

Over the past few decades, the market for technology has grown consistently and is emerging as a dominant platform for technology transfer. In 1983, the worldwide royalties and license revenues for technology were about 10 billion US dollars; by 2000, the figure had increased to 80 billion US dollars (Athreye and Cantwell, 2007); Gindley and Teece (1997) point to the increasing use of technology licensing as a source of revenue by companies such as IBM, Hewlett-Packard, Texas Instruments, and AT&T during the 1990s, and IBM was reported to have generated almost 1 billion US dollars from patent licensing in 1999 (Rivette and Kline, 2000). Given the size of licensing revenue, the market for technology has caught the attention of academic researchers and practitioners in the industry.

Companies with both research and development capabilities only commercialized innovations developed internally in the past, as traditional wisdom suggested that companies are more profitable from developing and commercializing innovations internally (Teece, 1988). When other companies were looking for technologies to license and commercialize, the technology holders were largely insular and suffered from the "not-invented-here" syndrome (Arora et al., 2001). However, the passage of the Bayh-Dole Act in 1980 encouraged American universities to explore possible sources of revenue by selling or licensing their patented innovations (Mowery et al., 2001). As a result, more useful and innovative technologies became available on the market and companies started to look for others' innovations. As the demand for technologies increased, more companies were willing to make their patents available on the market, and patented innovations started to be treated as tradable commodities (Arora et al., 2003). Consequently, companies began to shift their resources to technology transactions by establishing a technology management and intellectual property (IP) division.

While some companies aggressively licensed their patents, others were less active in selling or acquiring technologies in the market. It is, therefore, important to examine the factors that affect firms' licensing decisions and technology transactions to better understand the function of the technology market. Several theoretical and empirical studies analyzed firms' licensing decisions, but did not explicitly emphasize the role of firm size. This paper aims to analyze the licensing decisions and technology transfers with a particular emphasis on the impact of firm size.

The situation considered in this study is summarized as follows. Consider a patent holder who is capable of commercializing his patent but is also contemplating licensing it. If he has not commercialized it, licensing will not create competition in the product market and he can make positive licensing revenue. On the other hand, if he has commercialized the patent, licensing will invite competition and reduce his revenue in the product market (Arora et al., 2001). For a large firm with a significantly large market share, the loss in revenue from the increasing competition may outweigh the positive licensing revenue and the firm may therefore be reluctant to license the patent. A small firm with a small market share; however, may be more active in licensing because the licensing royalties are more likely to compensate for the loss in revenue due to increasing in competition. Thus, firms of different sizes may be very different in making the licensing decisions. Such decisions are mainly driven by profit, which is often related to the characteristics of the patent itself, its assignee, and the industry it belongs to.

The objective of this paper is to examine the differences between large and small firms in their willingness to license by incorporating the characteristics of usefulness to its assignee, importance, and innovativeness of a patent, market share of the patent holder, and the industry competition intensity. This objective is achieved by investigating these characteristics of patented technologies both on and off the market which are provided by large and small business enterprise sectors (BES). Only BESs with commercialization capabilities are considered because they can generate revenue from both the technology and product markets. Other patent assignees that do not possess such capabilities, such as universities, small research institutions and government research agencies, are excluded from this study. The study focuses on the supply side of the markets of technology, and restricts to licensing activities motivated by non-strategic factors.

The licensing decision of a patent holder is analyzed using the revenue versus competition framework developed Arora and Fosfuri (2003). Unlike Kim and Vonortas (2006) and Fosfuri (2006), this study focuses on the willingness of patent holders to license instead of the actual licensing activities themselves. Gambardella et al. (2007) investigated patent holders' willingness to license patents that were granted by the Europe Patent Office (EPO), where this paper analyzes patents granted by the United States Patent and Trademark Office (USPTO). Similar to Palomeras (2007), this paper looks at the determinants of technology licensing as motivated by non-strategic reasons, or pure-revenue licensing. However, this paper also considers firm size, includes characteristics at the firm and industry level, and refines the empirical analysis with a broader dataset.

This study is structured in the following way. Chapter two reviews and discusses the literature on licensing and the technology markets. Chapter three describes the theoretical background and constructs several testable hypotheses. After demonstrating the data collection process and empirical model in chapter four, chapter five presents and explains the results and implications of this study. The conclusion follows in chapter six.

Chapter 2
Literature Review

2.1 Use of Patents

A patent is the state-granted exclusive right that prevents anyone other than its owner from exploiting the technology for a limited period, and a technology license is an agreement whereby an owner of a technological intellectual property allows another party to use, modify, and/or resell that property in exchange for a compensation, which is called licensing fees or royalties. Giuri et al. (2007) list six uses of a patented technology by the patent holder, including internal use, licensing, cross-licensing, licensing and use, blocking competitors, and sleeping patents. Based on a survey questionnaire distributed in the U.S. manufacturing sectors, Cohen et al. (2000) found that there are a number of motives for obtaining patents: commercialization, licensing, the prevention of copying, preventing rivals from patenting similar and related inventions, leverage for negotiation, and the prevention of suits. In the big picture, these uses can be divided into two main groups: strategic uses and non-strategic uses. This generalization is supported by Ford and Ryan (1981), who suggest that fully-integrated companies license for either strategic or financial reasons.

In terms of strategic purposes, patents are not used directly to obtain financial returns, but to bring financial gains in the long run. Cohen et al. (2000) discovered that preventing others from patenting and commercializing, or blocking, is one of the main motives for U.S. manufacturing firms to patent. Another strategic usage of patents is trolling, an action in which one purchases patents solely for the purposes of aggressively extracting a licensing fee (Barker, 2005). Patent licensing can also be motivated by strategic considerations. Shapiro (2001) demonstrates that some patents are used for cross-licensing, especially in industries suffering from patent thickets, a dense web of overlapping intellectual property rights that a company must hack its way through in order to actually commercialize new technology, such as semiconductors, biotechnology, computer software, and the Internet. Shapiro and Varian (1998) suggest that establishing an innovation as the standard for the industry is also an incentive for a patent holder to license. Fulton and Yiannaka (2007) show that it is beneficial for the patent holder to strategically license a new product innovation to its competitors if it is unable to deter entry.

On the other hand, patents can also be applied for non-strategic incentives, mostly to commercialize the technology internally within a firm. Balasubramanian and Sivadasan (2008) found that the number of products produced by a firm increases when the firm patents. Another major non-strategic use of a patent is to license it to other firms only for royalties. Giuri et al. (2007) found that about 6.2% of the European Union (EU) patents are utilized in this way. Finally, a patent can be left unused, in which case is called a sleeping patent. These patents are usually considered unprofitable if they are commercialized and are, at the same time, unattractive for potential licensees. Palomeras (2003) explores the technological characteristics of a sleeping patent and asserts that some remain unused because they do not fit into their holder's core competency, though they may be valuable in other industries. This paper focuses on the non-strategic usage of patents, in particular those for internal uses and externally used for licensing purposes.

2.2 Technology Market, Technology Licensing, and Licensing Determinants

The abovementioned licensing activities show that on one hand there are companies willing to license their own patents, while on the other hand there are also companies that want to license patents from others. As a result, markets for different technologies, or patents, are formed. Arora et al. (2001) provide a concise definition of the markets for technology: they are markets for intellectual property that is licensed and its close substitutes—that is, the technologies or goods that are close enough substitutes significantly to constrain the exercise of market power with respect to the intellectual property that is licensed.

Recent growth in the technology market has prompted research on the licensing behaviour of firms. Assuming that the patent holder is the sole technology holder, Rockett (1990) suggests that choosing its competitor is an important motivation behind the licensor's behaviour, because the licensor will have to face competition after his patent has expired, which has a direct impact on his profits. Arora et al. (2001) relax the assumption of having a monopolistic technology holder and study how the revenue effect and rent dissipation effect influence the licensing decision of a patent holder. Arora and Fosfuri (2003) constructed a theoretical model showing that competition in the product market provides an incentive for a patent holder to license in the technology market, given that there are multiple technology holders. Then, based on this model and using results from an empirical study of large firms in the chemical industry, Fosfuri (2006) shows that the level of market competition and the size of a firm's market share affect its licensing incentive and actual licensing activities. Palomeras (2007) also conducted an empirical study which assumed that all the patents listed in that marketplace are placed there for non-strategic, or pure-revenue, purposes. With patents from the chemical and biological industries, he examined a firm's willingness to license its patents for pure-revenue purposes and found that the importance, innovativeness, and scope of a patent, as well as how it fits into the firm's core competency are key technology determinants that affect this willingness.

Without using the competition model, Giuri et al. (2007) use PatVal, a large and comprehensive survey of inventors in six European countries and covering patents across all industries, to show that the share of patents only used for licensing of small firms are larger than that of large firms. Kim and Vonortas (2006) also performed an empirical study on the determinants of technology licensing across all industries. They show that the stock of technological knowledge held by the licensor, the company's prior exposure to licensing, the growth rate of its primary sector, the strength of IPR protection, and the nature of the technology are all important determinants of whether or not the patent will actually be licensed. Additionally, they discovered that small firms with lesser technological and product complexity tend to license their technology through exclusive licensing contracts, while large firms which usually have higher complexity in their technology and product tend to license their technology through non-exclusive licensing contracts.

Research has also been conducted on the licensing strategies of firms that lack commercialization capabilities. Teece (1986) claims that innovative firms without commercialization capabilities may find it difficult to survive, even if they are one of the leaders in their field, unless there is a strong appropriability regime and contractual modes such as licensing agreements are used. While studying new-technology based firms (NTBF) in the biopharmaceutical industry, Kollmer and Dowling (2003) found that those NTBFs are often lacking commercialization capability. They found differences in the use of licensing strategies between NTBFs that are both fully and partially integrated. Davis (2005) also investigated the licensing strategies used by firms without commercialization capabilities. Essentially, the business model of such firms requires them to develop intellectual properties and then generate revenue solely by licensing them.

2.3 Firm Size and Innovation

There is a vast literature about the relationship between innovativeness and the size of a firm. Acs and Audretsch (1988) and Rogers (2004) show that differences in innovativeness between small and large firms are due to different behaviours towards innovation. Using outputs per unit of (formal) R & D input, Acs and Audretsch (1990), Kleinknecht et al. (1993), and Rothwell and Dodgson (1994) have all shown that small firms are more innovative and more efficient when it comes to innovation. On the other hand, Cohen and Klepper (1996) and Tether (1998) challenge the validity of the assumption made by previous researches: the economic value of innovations is unrelated to the size of the firm. Tether (1998), in particular, has come to the conclusion that the economic value of innovations is positively correlated to the size of a firm, and hence large firms are more innovative than small ones. Veugelers and Cassiman (1999) suggest that there is a positive but non-linear relationship between innovativeness and firm sizes. Rogers (2004) also found that the size of firms, as measured by the number of employees, is positively correlated to the innovativeness of manufacturing firms. These correlations do; however, vary from industry to industry. Lee (2005) shows that there is no relationship between patenting productivity and firm size in the pharmaceutical industry but that there is a positive correlation in the semi-conductor industry.

However, the above results regarding the relationship between firm size and innovation have focused only on the production market, while ignoring the technology market and the characteristics of the innovations and the firm in question. The only study to consider this issue in the technology market is Gambardella et al. (2007), which looked at the determinants of a patent that changed a firm's willingness to license, and whether or not the patent is actually being licensed. They determined that patent breadth, value, scope, and firm size all affect a firm's willingness to license, but only firm size significantly influences the actual licensing activity of a patent once the decision to license has been made. Although there are increasing patent transfers and licensing activities between firms, very few studies have discussed this topic.

Chapter 3
Theoretical Background and Hypotheses

3.1 Theoretical Background

Palomeras (2007) claims that the technological nature of a patent affects its technological opportunity, costs of transfer, and the creation of competitors, which, in turn, have an impact on the potential profit, and so the licensing decision is influenced. Meanwhile, the size of the patent holding firm also plays a key role in the licensing decision, because firms of different sizes are different in many ways. They often have different approaches to the use of their patents, have significantly uneven distribution in their resources such as complementary assets, and have disparate market strategies in obtaining and maintaining market share.

The licensing decision is driven by the total effect of licensing, or the change in profits a firm made from licensing. Such profits consist of those obtained from the product market and those from the technology market. In the former case, where the patent is developed and commercialized internally, the profit depends on a number of factors, such as the technological opportunities created by the patent, the availability of complementary assets, and the competition environment in the product market. In the latter case, where the patent is licensed, the profit depends on royalties and transaction costs.

The total effect of licensing a patent is the potential profit gained through licensing by its assignee, which is the sum of the revenue effect and rent dissipation effect (Arora and Fosfuri, 2003). The revenue effect refers to the economic impact in the technology market which the patent holder experiences as a result of licensing, and its magnitude is affected by two components: the technological opportunity of the patent for its assignee (Shane, 2001) and the transaction costs (Williamson, 1991). In contrast, the rent dissipation effect describes the economic impact in the product market in the form of a loss of profit from the product market due to an increase in product competition caused by licensing (Arora and Fosfuri, 2003). A firm generally considers the magnitude of each effect and makes their licensing decisions based on the total estimated effect. Key determinants in a firm's licensing decisions therefore include the technological opportunity of its patent, the transaction costs, and the creation of its own competition.

The technological opportunity of a patent is the chance for a firm to gain a profit by commercializing it, where the firm in question can be either the patent holder or a potential licensee. The magnitude of the opportunity is positively related to the size of the product market, which affects the revenue that the potential licensees can extract from the licensed technology (Fosfuri, 2006), and in turn plays a big part in the negotiation of the licensing fees. Before a patent holder makes a licensing decision, it first must check whether the patent has already been internally developed and commercialized. If the patent is commercialized, the assignee is making revenue from the product market. Should another firm be also attracted by the technological opportunities created by the patent and decides to license it, the assignee will potentially make a profit from the technology market at the expense of the loss in revenue in the product market. However, if the patent assignee decides that it is not justified to commercialize the patent, the firm will not be able to generate any profit from it except by licensing or selling it. Therefore, the technological opportunity of a patent has a direct impact on the revenue and rent dissipation effect of its holding firm, regardless of whether it is commercialized or not.

Transaction costs are the expenses a firm incurs during the licensing process, and include the coordination costs (Arora et al., 2001) and the motivation costs. Coordination costs are the expenses for coordinating the licensor and licensee, and consisted of search costs (Palomeras, 2007), as searching for suitable licensees can take a long time and a high cost (Contractor, 1981); and administration costs such as contract writing (Arora and Fosfuri, 2003). Motivation costs, on the other hand, are the potential economic losses incurred by the patent holder due to the opportunistic behaviour of a potential patent licensee. Such costs are a result of information asymmetries, the technological distance between the domains of licensor and licensee and the tacitness of the patent (Arora et al., 2001). Garicano and Kaplan (2001) show that transaction costs can be reduced in the setting of internet business-to-business (B2B) market, as searching costs in this domain are trivial, and motivation costs are lowered by the minimization of information asymmetries. Arora and Fosfuri (2003) found that lower transaction costs are required for licensing patents with stronger protection.

The creation of a firm's own competition refers to the increase of its competition in the product market due to additional competition in the same market. Assuming that a patent creates a technological opportunity, its assignee is likely to commercialize the patent and potentially makes a profit in the product market. By licensing its patent, the patent assignee creates competition in the product market. As a result, the profits it makes in the product market may decrease—a result known as the rent dissipation effect.

The magnitude of the three main features described above are influenced by the nature of the technology (Fosfuri, 2006; Kim and Vonortas, 2006; Palomeras, 2007), the nature of the firm (Vonortas, 2003), and the nature of the industry (Veugelers and Cassiman, 1999; Shane, 2001;Gambardella, 2007). A number of characteristics at the technology, firm, and industry level are used to capture these natures. Therefore, these characteristics remained as important factors for a patent holder when making licensing decisions, and will be discussed in depth in the next section.

The size of the patent holding firm; however, has not previously been considered as a key factor in the literature on licensing decisions. In fact, firms of different sizes vary in their licensing policies. Using the empirical result of EU patents, Giuri et al. (2007) found that 10% of patents owned by large firms are licensed and 40% are unused. The corresponding percentages for small firms; however, are

26% and 18%. Gambardella et al. (2007) also show that a patent is more likely to be licensed if it is owned by smaller firms. These results clearly demonstrate that large firms are less active in the technology market than small firms. Large firms often have greater resources than their smaller counterparts, including better complementary assets and larger marketing and advertising budgets. With these resources, they are able to manufacture their products at a lower cost and market them more aggressively. As a result, it is more likely that large firms will enjoy larger share of the product market. In this case, the decision to license the originating patent of the products will create competition in the product market, and may lead to the rent dissipation effect outweighing the revenue effect. Therefore, large firms may be less willing to license the patents that they have commercialized. Small firms, on the other hand, maybe at a financial advantage after licensing their patents, because the revenue effect is bigger than the rent dissipation effect when their market share is small. The impact of firm size on each characteristic, the licensing determinants, and consequently the licensing decisions are explained in detail in the following section.

3.2 Characteristics at the Technology, Firm, and Industry Level and Hypotheses

The nature of a patent, its holder, and the market it belongs to can affect its technological opportunity, its transaction costs, and the creation of competition for its holding firm, which consequently has an impact on the potential profit from licensing. In the literature, a number of characteristics are used to capture these natures. For example, the characteristics of a patent include usefulness, technological value, scope, and innovativeness; the market share, the complementary assets, and the experience in writing licensing contracts were used to represent the nature of the firm; and competition intensity was used to capture the nature of the market and the industry. In the following, the impact of some of these characteristics will be discussed, along with the hypotheses.

3.2.1 Usefulness

The usefulness measures how useful or important a patent is to its assignee. Naturally, the more useful that a patent is to its assignee, the more likely it is to be further developed internally, such as by commercializing it and developing other innovations based on it. Firms are more likely to commercialize innovations with which they have some expertise, at either the technological, manufactural, or commercializational level. The reason for this is that they are more efficient in commercializing as they have more knowledgeable researchers, better complementary assets, and competitive advantages in manufacturing (Gambardella et al. 2007). Such expertise is referred to as the *core competency* of the firm. Therefore, the more closely related that an innovation is to the core competency of the firm, the more useful it is to them. However, only core competency at the technological level will be considered here.

As a patent is commercialized by its assignee, profit will potentially be made in the product market. When the assignee firm licenses the patent to another company that competes in the same product market, it is creating its own competition. There is great potential in this situation for the rent dissipation effect to impact the assignee. Therefore, firms must decide whether licensing their patents is justified; essentially, they must determine—whether or not the rent dissipation effect will outweigh the revenue effect of licensing. Palomeras (2007) claims that unexploited technologies are the most likely candidates to be made available for pure-revenue licensing, because the patent assignees do not face competition in the product market from the licensees. However, this is the point where firms of different sizes differ when making their licensing decisions.

Hypothesis 1: Large firms are less willing to license patents that are useful to them comparing to those that are not useful to them, whereas small firms are more willing to license patent that are useful to them.

The first hypothesis can be analyzed in two cases: that in which the patent creates technological opportunities, or that in which it does not. In the latter case, its assignee will not attempt to commercialize it, and hence the assignee will not make any profit from it in the product market. Then, if some other company license and commercialize it, the rent dissipation effect will be zero. As a result, the total effect is always non-negative, and so all firms will be willing to put the patent on the market, regardless of their size.

On the other hand, when the patent creates technological opportunities, it is likely that its assignee will commercialize it and thus gain profit from it in the product market. Since it creates technological opportunities, other companies may find it attractive and possibly attempt to license it. If the assignee is a large firm, in an industry in which the firm enjoys core competency, it is more likely that the firm has a large market share in the product market. As a result, the patent assignee creates its own competition with a significant rent dissipation effect, which is comparable to the revenue effect of licensing, and potentially has a negative effect on the overall profit. Also, Teece (1986) argues that firms with complementary assets have a lower propensity to license, and large firms are likely to own those assets for innovation (Gambardella et al., 2007). Therefore, large firms are less willing to license a patent that creates technological opportunities. In contrast, the rent dissipation effect is not as significant if the patent assignee is a small firm, because a small firm is often restricted by scarce resources, and is less effective in manufacturing, marketing, and advertising. Hence it is more likely that a small firm will own a smaller market share in the product market. Therefore, even if the patent itself is useful, a small firm will still be willing to list it on the market.

3.2.2 Technological Value

The *technological value* of a patent refers to its technological significance in its respective field. Shane (2001) refers this characteristic to the importance of the patent, and it is often connected to the economic value of the patent, as Harhoff et al. (1999) and Hall et al. (2005) show that these variables are positively correlated. Therefore, the higher the technological value of a patent, the more technological opportunities it creates for its assignee, in both the product market and the technology market, as it also attracts potential licensees. Using different proxies for the technological value of a patent, Gamberdella et al. (2007) have shown that the economic value of a patent is positively correlated the patent assignee's willing to license patents and the actual licensing activities.

3.2.3 Scope

The *scope* of a patent is the breadth across which the product that it embodies will be protected. Klemperer (1990) defines scope as the horizontal product space protected by the patent. Gilbert and Shapiro (1990) suggest that a broader patent allows the innovator to earn a high flow rate of profits during the lifetime of the patent. Lerner (1994) demonstrates that the patent scope of a firm's patents has a positive effect on the value of the firm. Therefore, scope can be determined from two perspectives: technological, and economical. Patents with a larger scope tend to be better protected. As Merges and Nelson (1990) state, the broader the scope, the larger the number of competing products and processes that will infringe on the patent. Arora and Fosfuri (2003) and Anand and Khanna (2000) found that patents with stronger protection would incur lower transaction costs, and patents with lower transaction costs are more likely to be licensed. Also, the larger the scope of a patent, the more applications it has, the more technological opportunities can be found for it in different industries, the higher the number of products that can be embodied by it, and therefore, the lower the chance that its assignee will create competition when licensing it. As a result, patents with a larger scope are more attractive to the potential licensees, and the patent holder has a higher willingness to license (Gambardella et al., 2007; Palomeras, 2007).

3.2.4 Innovativeness

The *innovativeness* of a patent refers to the degree to which it builds on previous innovations. An innovative innovation can be largely improved in terms of technology or costs compared to the original product, and hence capable of replacing the latter in the market.

Commercializing such an innovation often requires new complementary assets and a change in the organizational environment (Tushman and Anderson, 1986). When large firms are market incumbents, they have less incentive to make radical improvements to their current products, and hence are less productive to exploit very innovative innovations (Henderson, 1993). For instance, consider a large company that owns a highly innovative patent which can be developed into a new product that is a direct substitution of one of the firm’s current products. If it chooses not to commercialize the patented innovation, to avoid the new product forces the incumbent out of the market, it will not license the patent to other companies. These patents will instead end up being used strategically to block rivals (Hall and Ziedonis, 2001). On the other hand, if the company does commercialize the patent, then licensing the patent will create competition of its own, which causes profit dissipation and leads to potential decreases in profit. For these reasons, large firms are less willing to license highly innovative patents. Meanwhile, the willingness of small firms to license highly innovative patents is ambiguous since they are more flexible in making radical changes, which gives them a competitive advantage in the product market, and makes them reluctant to license. However, they may also benefit more by licensing innovative patents if they do not have a large market share. Looking at firms of different sizes, Palomeras (2007) shows that the market incumbent has an incentive to license patents that are more innovative, because high coordination costs can be alleviated in a market that is not a typical distant market. To summarize, the following hypothesis will be tested:

Hypothesis 2: The patents listed on the market by large firms are less innovative than those which they do not list.

3.2.5 Market Share

The term *market share* refers to the portion that the patent assignee dominates of the product market which a particular patent has been commercialized. It is assumed here in order for this to make sense, that the patent has been commercialized by the patent holder and that the commercialized product is available in the product market. Fosfuri (2006) shows that, in an empirical study that omits small firms, that the larger the licensor's share in the product market, the smaller its rate of technology licensing. In other words, market share is negatively correlated to the patent holder's actual licensing activities.

Also, it is worthwhile to note that market share in the product market of a firm is a crucial factor in determining the magnitude of the rent dissipation effect, and hence the total effect, which in turn influences the licensing decision. When a firm has a small market share, rent dissipation will be insignificant, and the total effect is likely to be positive. Then, the firm will have an incentive to license its patent, and then to list the patent on the market. On the other hand, if the market share is large, the rent dissipation effect may be large enough to outweigh the revenue effect. The firm will then be reluctant to place its patent on the market.

As discussed before, large incumbents are more likely to have a large market share, as they have more resources compared to their small counterparts. As a result, large firms are less willing to license their patent in order to protect their market share. The magnitude of the rent dissipation effect and the propensity to license; however, is ambiguous for small firms. They may be reluctant to license if they have a large share in the market for the same reason as large firms, but meanwhile they may not have the resources to defend their market share in the long run, which force them to license and transfer the source of revenue from the product market to the technology market. The above arguments lead to the following hypothesis:

Hypothesis 3: The larger the share that a firm has of the market in a technological class, the less likely the firm is to license patents belonging to that technological class.

3.2.6 Competition

Competition refers to the competition intensity of the product market of the product that embodies the originating patent, and the same assumption as the market share characteristic is made. Consider an extreme case, in which a firm faces no competition in the technology market, and hence none in the product market. Then, as a monopoly, it has no incentive to license its patent. However, when the number of technology holders increases, its willingness to license may also increase. Using an empirical study, Fosfuri (2006) demonstrates that there is an inverted U-shaped relationship between the rate of actual technology licensing and the number of potential technology suppliers. In other words, starting with a situation in which there are no competitors, a patent holder's actual licensing activities increase while the number of technology holders also increases. However, when the number of technology holders reaches a certain value, the rate of technology licensing decreases as the number of technology holders increases, due to a bounded number of potential licensees and the increase in competition in the technology market. Assuming that there are multiple technology holders, Arora and Fosfuri (2003) developed the revenue versus competition model that shows a patent holder would have an incentive to license even if the rent dissipation effect outweighs the revenue effect, due to the competition in the product market. Using empirical data from Europe, Gambardella et al. (2007) show that there is a positive correlation between the number of technology producers and both the firm's willingness to license and actual licensing activity.

Comparing firms of different sizes, the willingness to license for large firms is higher as competition gets more intense, and is ambiguous for small firms. As a market becomes more competitive, there is a higher chance that other technology holders will license their technology to new entrants. In the former case, since the originating large firm cannot deter entry, it would simply try to license its technology like the other technology holders in order to gain royalties. As a result, their propensity to license increases with the intensity of competition. On the other hand, small firms may not attempt to block entry even if the competition is not intense as they find it difficult to defend their market share in the long run. So, instead of making profit in the product market, they do not hesitate as much to create competition and make profit in the technology market regardless of the competition intensity. Therefore, impact of competition factor on willingness to license for small firms is ambiguous. Also, Fosfuri (2006) claims that small firms face a less intensive trade-off between revenue effect and rent dissipation effect, but he does not actually show evidence to support his assertion. His claim will be tested in this paper along with the following hypothesis:

Hypothesis 4: The more intense the competition in the product market, the higher the willingness of a large firm to license its patents.

Chapter 4
Data and the Empirical Model

In order to show evidence in support of the hypotheses, an observational study, a method for drawing inferences about the effect of a treatment on subjects, is conducted. In this study, the treatment is the availability of patents on the market, and the result of the impact of this treatment on the subject is not deliberately controlled by the experimenter as in a controlled experiment. Instead, the variables are collected in such a way that those of the treated group and of the controlled group are collected. Also, there are two reasons why patented technologies are used as a measure of technologies in the market: their representability as the technologies traded on the market and data availability.

For data collection, patents that are both on the market and not on the market were first collected. Second, these two groups were further broken down into four groups by separating the size of the patent assignees. Third, the characteristics of the patents in these four groups were gathered. By performing a statistical analysis of the characteristics of the market group and the control group of both small and large companies, and comparing the result between them, one can discover the impact of assignees' size on the variation in characteristics. As a result, the differences in licensing decisions can be determined. The steps in data collection and the detail of the empirical model will be explained below.

4.1 Data Collection

As mentioned above, the characteristics of patents that are on the market and those that are not on the market must be collected from both small and large firms. This can be done through the following steps. First, patents made available by their assignees on the market are gathered. Second, in order to study the licensing decisions of small and large firms, the list of patents in each group must be subdivided into two market groups according to the size of their assignees. Third, the control groups of these two market groups are obtained by matching the name of the assignee, the application year, and the technological class, which is represented by the International Patent Classification (IPC) code. As a result, four groups of patents are formed: the market group for small firms, the market group for large firms, the control group for small firms, and the control group for large firms. The fourth step involves adjusting the ratio of market group to control group of large firms so that it is similar to that of small firms by selecting random samples from the large firms control group. The fifth and final step is performed, after the patent list for each group is obtained; patent data for the independent variables of the model are collected for statistical analysis. The following paragraphs explain the details of each step in the data collection process.

Recall that the first step in data collection is to collect patents for the market group. Note that there are many marketplaces and it is not feasible to collect patents from all of them. Therefore, an internet marketplace is selected as representative. Following Palomeras (2007), Yet2.com (www.yet2.com), arguably one of the largest and most comprehensive internet technology marketplaces, was chosen. It is assumed that this marketplace represents the whole patent market. In other words, if a patent is not listed in the marketplace mentioned above, it is assumed that the patent is not listed in any other marketplace. Palomeras (2007) also asserts that internet marketplaces attract licensing activities for non-strategic, or pure-revenue, purposes, so he assumes that all patents in Yet2.com are listed for such purposes. This paper adopts the same assumption.

Next, the whole list of patents obtained from the marketplace must be trimmed in order to satisfy the three requirements of the focus of the research: each patent must have only one assignee, the assignee itself must be a BES, and the BES itself must be capable of generating revenue from the product market.

The first requirement removes some confusion in making licensing decisions created by multiple assignees. The second requirement ensures that the patent assignees in the market group match the focus of the research. The type of assignees can be found using online company databases such as Mergent Online and Hoovers. The third requirement ensures that the patent assignees have not been forced to list them due to their inability to generate revenue through the product market. The ability of a company to generate revenue through the product market is determined by whether or not it sells its own product, and this can be checked at the official website of the company.

In the second step, the resulting list of patents is further divided into two groups according to the assignee size. The definition of a large firm is one that has over 500 employees (Acz and Audretsch, 1988), while anything below that is considered to be a small firm, or, more officially Small and Medium Enterprises (SMEs). Here, the two groups of patents in the market group are collected: the one for large firms has 917 patents, and the one for small firms has 30 patents.

In step three, patents from the control group must be collected. With those two market groups of patents, the corresponding control groups can be found by matching the name of assignees, the filing years of the patents, and the IPC codes. There is an assumption in matching of the names of assignees: subsidiaries can make their own decisions. For example, even though it is a subsidiary of the Textron Inc., Bell Helicopter is assumed to be authorized to make its own licensing decisions independently. Therefore, a patent assigned to Textron Inc. will not be in the control group of patents owned by Bell Helicopter. Also, matching IPC codes involves not only the first code, but the whole list. For example, a patent in the market group has a few distinct IPC codes. Then, any patents with an IPC code that matches anyone of the patent's IPC codes are considered a part of the control group, given that the name of the assignee and the filing year also match. Lastly, the market group includes small firms with patents that were filed between 1991 and 2006. As a result, the patents in the control group of small firms have been filed during that same period frame as well. The patents in the market group of large firms were applied from 1983 to 2004, so the patents in the corresponding control group have to be applied between 1983 and 2004. After matching those variables, one also needs to check that not all the patents owned by a company are listed on the market. Otherwise, it will be impossible to find a control group for those patents and there will be nothing with which to compare them.

Here, the resulting list of patents in the control group is very long for large firms, and is very short for small firms. However, for purposes of comparison, the ratio of the market group size to control group size of both small and large firms should be similar. Therefore, the fourth step is to form a new control group of large firms by selecting a random sample from the original control group of large firms. To be specific, 2712 patents were chosen from 81133 patents in the population. The patent lists of the market group and control group for small firms and large firms were then obtained.

Finally, in the fifth step, the patent data for the independent variables and covariates of the model for all groups have to be collected. Since the application years of some of the patents are after 1999, the NBER patent data, which covers only up to 1999, cannot be used. As a result, the retrieval of the patent data from the USPTO website was done by a script.

Additionally, it was found that the number of forward citations for patents granted for less than ten years is much less than those granted for more than ten years. The reason for this is that normally a patent receives most of its citations in the first ten to fifteen years after its application; then, for a patent applied within the last ten years, it would not have received all of its citations. The problem is called the patent citation truncation. To solve the problem, the number of forward citations and self-forward citations for all patents in the data set are transformed using the "fixed-effects" approach developed by Hall et al. (2001). The key function of this approach is to have one able to compare forward citations of patents applied in different year directly. It assumes that although the actual average number of forward citations of all patents applied in any year may not be the same as that in another year, the difference is not caused by "real" technological impact, but rather by "artifacts" of changes in patent examination practices, such as changes in patent examination policy. As a result, the real average number of forward citations of all patents applied in any year is the same across all years. For example, if one wants to compare ten forward citations of a patent applied in 1994 to ten forward citations of a patent applied in 2004 using the "fixed-effects" approach, he would compare the values of ten divided by the average number of forward citations of all patents applied in 1984 to that applied in 1994. With this approach, the weight of a forward citation of patents applied in different years may be different, but the average forward citations of patents filed in each year are assumed to weight the same across all years. Such calculations use the average number of forward citations per patent in each year, as shown in Table 1.

Lastly, it is worthwhile to mention that the data collection of patents from Yet2.com was performed during early 2008, and the retrieval of patent data from the USPTO website started in mid-2008, and ended in late 2008.

4.2 Empirical Model

A regression analysis is performed to test several hypotheses described in the previous section. In order to discover the correlation between a firm's willingness to license a patent and the characteristics of the originating patent, its assignee and the industry it belongs to, a binary variable known as "Market" is the dependent variable of the regression model. Market is considered equal to one if the patent is made available on the market, and equals zero if not. Since the dependent variable is binary, the probit model is adopted for empirical tests.

Year	Average citations
1983	11.42892284
1984	11.77170877
1985	12.05813175
1986	12.48215684
1987	12.4283635
1988	12.37814569
1989	12.38897181
1990	12.50577745
1991	12.57038495
1992	12.64659339
1993	12.4510522
1994	12.20454564
1995	11.32832896
1996	10.80642896
1997	9.519262153
1998	7.833539295
1999	6.106434182
2000	4.171506135
2001	2.681135408
2002	1.625145718
2003	0.890100333
2004	0.445716994
2005	0.215177267
2006	0.08606414

Table 1. Average number of forward citations per patent for each year

Several requirements must be satisfied in order for the results of the probit regression to be correctly interpreted, including the lack of undue influence of individual observations on the fitted model, the absence of multicollinearity, and the statistical independence of the observations. When running regression for a similar problem, Palomeras (2007) uses a probit random effects model because his data did not satisfy the last requirement. This study uses the tests in the statistical package Stata to verify whether the requirements are met, and to fix it if they are not. To detect the influential observations, Cook's D is used. The value of Cook's D for an observation is always non-negative; and the higher it is, the more influential the observation is. The rule of thumb when using this technique is that if an observation has a Cook's D value greater than 4/n - where *n* is the total number of observations in the sample - it may merit further investigation. Next, the variance inflation factor (VIF) and tolerance (the inverse of VIF) are used to check for multicollinearity. The rule of thumb here is that, if a variable has a VIF value above 10, or a tolerance value lower than 0.1, it requires further investigation. Lastly, the observations may not be independent between firms. For example, the patents owned by a certain firm may, on average, have a higher number of forward citations than those owned by other firms. In this case, therefore, the cluster option is applied so that the data satisfies the requirement for independence of observation.

Notice, also, that a number of independent variables are log transformed to reduce their skewness and are added one before transformation to avoid mathematical error. These variables include the number of forward citations, backward citations, self-forward citataions, self-backward citations, claims, and inventors.

4.2.1 Independent Variables

In order to predict the dependent variable, variables that capture the characteristics at the technological, firm, and industry level and covariates are used.

Usefulness: There are two proxies representing such characteristics: the technological core and the number of self-forward citations. As mentioned above, each firm has its core competencies. Focusing on the technological perspective of the core competencies, the closer the patent is to the firm's core, the more likely it is to be commercialized by the firm, and hence the more useful it is to the firm, ceteris paribus. Therefore, the technological core can be employed as another proxy for usefulness. It is a binary variable, which equals one if its technological class is a core of its assignee, and equals zero otherwise. This is a measure that was first used by Song et al. (2003), and then revised by Palomeras (2007). According to the latter, a technological class is identified as a core of a firm if it has more than 5% patent share of the patents granted to the firm within a certain period. The period of the application year of the patents for the proxy here is the same as the application year of the patents both in the market group and in the control group. Also note that the technological class of a patent is identified using the US technological class system.

A self-forward citation of a patent is a forward citation that is assigned to the same assignee as the originating patent. When a patent is cited by patents from the same firm, it must be valuable to the firm in terms of its technological aspect, as the firm has further internally developed it and based other innovations on it. Hall et al. (2005) show that the number of patent self-citations in a firm has a positive effect on the market value of the firm's intangible stock of knowledge. Therefore, the higher the number of self-forward citations that a patent receives, the more useful that patent is to the firm.

Technological Value: This characteristic is represented by the proxy of the number of forward citations, which is a simple count of the number of patents that have cited the originating patent. The higher the number of forward citations that a patent has, the higher its technological value. This is, in fact, one of the most common and widely used proxies for evaluating patents in the literature. Trajtenberg (1990), Harhoff et al. (1999), and Hall et al. (2005) show that the number of forward citations is positively correlated to the estimated economic and technological value of the patented innovation. Hirschey and

Richardson (2004) also discovered that the number of forward citations has a positive effect on a firm's potential performance in the stock market.

Scope: The scope of a patent is the breadth across which the product embodied by it is protected. It can be determined from both the technological and economic perspectives. Therefore, there are two distinct proxies that can represent such characteristics, *generality* and the *number of claims*. The first proxy represents the technological scope, and the second one represents the economic scope.

Generality is a Herfindahl-typed index that calculates the diversification of the technological classes of a patent's forward citations and was first used by Trajtenberg et al (1996). The variable explains how broad the technological classes are of patents that have cited the originating patent. Since its creation, generality has become one of the standard measures of the scope of a patent. For example, Hall et al. (2001) included it in the widely-used NBER database.

The number of claims in a patent represents how well the patent is protected in terms of its applicable functionalities. Lanjouw and Schankerman (1999) and Palomeras (2003) use the number of claims as a proxy for patent scope, and claim that the higher it is, the better the patent is protected, and hence the broader the scope.

Innovativeness: Two proxies are used here to capture the innovativeness of a patent: *originality* and the *number of backward citations*. Originality of a patent, similar to generality, is a Herfindahl-typed index that calculates the technological diversification of a patent's backward citations. It shows the breadth and the diffusion of the technological fields of the patents that cited by the originating patent. If the patents cited by the originating patent belong to a narrow set of technological classes, the value of originality is low. Originality was first used by Trajtenberg et al. (1996), and has become one of the standard quality measures of patent in the NBER patent data (Hall et al, 2001). Palomeras (2003) suggests that the lower the degree of originality, the lower the degree of innovativeness, as it is more likely that the innovation makes a sequential, rather than radical, improvement.

The number of backward citations is a simple count of the number of patents that have been cited by the originating patent. It was first used by Lanjouw and Schankerman (1999) as a proxy for the innovativeness of a patent, who suggest that the lower the number of backward citations, the higher the innovativeness, as the patent depends less on previous knowledge.

Market Share: It refers here to the portion that the firm holds of the product market, in which a given patent is commercialized. However, the actual measures of market share are very difficult to obtain for three reasons. First, it is difficult to discover whether or not a patent has been commercialized. Second, if the patent has been commercialized, it is difficult to find the corresponding product in the market. Third, the market share of the product market for each firm is also difficult to obtain. Therefore, instead of measuring the share that a firm has of the product market, a similar method proposed by Gambardella et al. (2007) for capturing intensity of competition in the product market, the market share in the technology market of the firm is obtained.

The market share proxy now refers to the portion held by the firm of the industry in which the U.S. primary technological class of the patent exists. It is calculated by finding the number of patents applied from 1983 to 2006 - which is the same as the application year of all the patents in the study - that has the same U.S. primary class and subclass as the originating patent. The market share of a given firm is the percentage of its share of all patents.

Competition: The *Competition* index refers to that within the product market that embodies the originating patent. However, similar to market share, it is not easy to discover the actual value here. Therefore, the proxy for competition is adjusted to that of the technology market of the technological class of that patent. Gambardella et al. (2007) use a proxy that measures the technological competition of a technological class by finding the share of the patents held by the top four applicants in each 4-digit IPC codes. They claim that competition within the technology market is correlated to that within the product market. This paper uses the same proxy, except that the U.S. primary class and subclass is used for matching technological classes instead of IPC codes. Note that in this study the shares of the top three firms are used because these give better results than the top four and top five firms.

Covariates: Two sets of covariates, or controls, which represent patents and firms, are used in this model. At the technological level, the number of self-citations made, the number of inventors and filing year of a patent are all used, following Palomeras (2007). The first variable represents the internal flow of knowledge (Hall et al., 2001), and is crucial to capture if one wants to measure the true meaning of external flow of knowledge, or citations. The number of inventors indicates the amount of tacit knowledge and knowhow that may be useful for the patent, since knowhow can smoothen the transaction and potentially lower the transaction cost. The last technological variable is the filing year, or the application year, of a patent. This is important because it takes into account technological changes over time, and is especially useful for industries in which technologies grow at a fast pace. At the firm level, USfirm, a dummy variable that tells whether or not the patent holder is a U.S. firm, is used. This variable also tells whether or not the holder has engaged in business activities in the U.S. and is particularly true for small companies. As a result, non-U.S. firms are less concerned about the rent dissipation effect, because they compete in different product markets.

Variable	Description	Characteristic
Core	Dummy, equals to 1 if the patent belongs to the technological core competency of the assignee	Usefulness
Selfcr	The number of patent citations received that have the exact same assignee name	Usefulness
SelfcrFix	Same as the above, but transformed using the "fixed-effects" approach	Usefulness
Creceived	The number of patent citations received	Technological value
CreceivedFix	Same as the above, but transformed using the "fixed-effects" approach	Technological value
Claims	The number of claims of the patent	Scope
Generality	The Herfindahl index on the spread of the technological classes of citation received	Scope
Cmade	The number of citations made; the lower the index, the higher the innovativeness	Innovativeness
Originality	The Herfindahl index on the spread of the technological classes of citation made	Innovativeness
MarketShare	The market share of the assignee in the product market of the product that embodies the patent	Market share
Competition	The competition intensity of industry that the patent belongs to; the lower the index, the more competitive it is	Competition
Selfcm	The number of patent citations made that have the exact same assignee name	Technological Control
Inventors	The number of inventors of the patent	Technological Control
Filedyr	The filed year of the patent	Technological Control
USfirm	Dummy, equals to 1 if the patent assignee is a U.S. BES	Firm Control

Table 2. Summary of variables

Chapter 5
Empirical Analysis and Implications

Using the Cook's D, influential observations are detected and deleted from the whole database. The size of the patent sample then decreases from 3629 to 3521 for large firms, and from 108 to 101 for small firms. Tables 3 and 4 show the descriptive statistics for variables of patents from large and small firms, respectively. Tables 5 and 6 demonstrate the VIF and tolerance of the variables. Observe that none of the VIF values is greater than 10, which means that there is no multicollinearity problem present here. Table 7 shows the estimations of the probit model for both large and small firms. Notice that the influential observations have already been eliminated and are not included in these tables.

The estimated results for both variables of the technological core and the number of self-forward citations has provided solid evidence for the first hypothesis. Although the coefficient of the former for small firms is positive but not statistically significant, that of large firms is negative and strongly statistically significant. The other variable, self-forward citations, has also provided even stronger evidence. Its coefficient for large firms is negative and strongly statistically significant, which agrees with the technological core variable, and that of small firms is positive and also strongly statistically significant. The probit estimation demonstrates that the more self-citations received by a patent held by a large firm, or the closer the patent is to the firm's technological core, the less likely it is that the patent will be listed. In other words, large firms are less willing to place their useful patents on the market. On the other hand, unlike their larger counterparts, small firms are more willing to license their useful patents. Therefore, these coefficients convincingly support the first hypothesis.

The second hypothesis claims that the patents listed on the market by large firms are less innovative than those that they do not list, and there are two proxies that capture the innovativeness of the

Variable	N	Mean	Std. Dev.	Min	Max	Market = 0 Mean	Market = 1 Mean
Core	3521	0.3001988	0.4584094	0	1	0.3272929	0.2105263
Selfcr	3521	0.8136893	2.399324	0	48	0.8402367	0.7258262
SelfcrFix	3521	0.09659	0.2802068	0	3.845489	0.1025668	0.0768088
Creceived	3521	8.580801	13.50805	0	150	8.086169	10.21787
CreceivedFix	3521	0.8840642	1.252701	0	11.93281	0.8393187	1.032157
Claims	3521	15.7069	11.69282	1	146	15.4057	16.70379
Generality	3521	0.5435175	0.3484431	0	1	0.5294635	0.5900314
Cmade	3521	12.13831	18.98118	0	391	12.01701	12.53978
Originality	3521	0.471656	0.2894332	0	1	0.4633966	0.4989919
MarketShare	3521	0.0515402	0.0850495	0	1	0.058132	0.0297234
Competition	3521	0.2395129	0.162979	0.027	1	0.2557426	0.185798
Selfcm	3521	1.000852	2.642367	0	48	1.058802	0.8090575
Inventors	3521	2.464641	1.588654	1	18	2.470784	2.444308
Filed	3521	1994.853	5.547535	1983	2005	1994.641	1995.553
USfirm	3521	0.8230616	0.3816707	0	1	0.8213757	0.8286414

Table 3. Descriptive Statistics for variables of patents from large firms

Variable	N	Mean	Std. Dev.	Min	Max	Market = 0 Mean	Market = 1 Mean
Core	101	0.9207921	0.27141	0	1	0.9210526	0.92
Selfcr	101	0.7029703	1.931551	0	13	0.5526316	1.16
SelfcrFix	101	0.5028711	1.714853	0	11.61924	0.401047	0.8124164
Creceived	101	8.653465	13.67438	0	65	8.960526	7.72
CreceivedFix	101	2.349861	4.139283	0	23.23848	2.40799	2.173148
Claims	101	19.84158	16.85451	1	103	18.11842	25.08
Generality	101	0.4913558	0.3596369	0	1	0.4610898	0.5833642
Cmade	101	24.26733	25.05789	1	159	25.18421	21.48
Originality	101	0.5647358	0.2711502	0	0.9060642	0.5698554	0.5491723
MarketShare	101	0.0250099	0.0288851	0	0.105	0.0225395	0.03252
Competition	101	0.1982574	0.1180214	0.037	0.708	0.2110263	0.15944
Selfcm	101	0.6336634	0.8913223	0	4	0.6315789	0.64
Inventors	101	3.405941	2.871161	1	16	3.763158	2.32
Filed	101	1999.614	4.022363	1992	2006	1999.395	2000.28
USfirm	101	0.8910891	0.3130811	0	1	0.8815789	0.92

Table 4. Descriptive Statistics for variables of patents from small firms

Variable	VIF	1/VIF
Core	1.13	0.883014
LogSelfcrFix	1.37	0.730743
LogCreceivedFix	1.4	0.716359
LogClaims	1.07	0.935992
Generality	1.06	0.94563
LogCmade	1.47	0.680935
Originality	1.27	0.789874
MarketShare	1.71	0.584991
Competition	1.86	0.537245
LogSelfcm	1.34	0.747781
LogInventors	1.09	0.920673
Filed	1.22	0.820002
USfirm	1.37	0.731855
Mean VIF	1.33	

Table 5. Variance inflation factor and Tolerance for variables of patents from large firms

Variable	VIF	1/VIF
Core	1.18	0.848594
LogSelfcrFix	1.9	0.527539
LogCreceivedFix	1.94	0.515184
LogClaims	1.31	0.765289
Generality	1.39	0.718849
LogCmade	2.22	0.45128
Originality	1.77	0.564161
MarketShare	1.52	0.658632
Competition	1.36	0.737202
LogSelfcm	1.51	0.662649
LogInventors	1.74	0.57409
Filed	2.15	0.464974
USfirm	1.27	0.788615
Mean VIF	1.63	

Table 6. Variance inflation factor and Tolerance for variables of patents from small firms

Variable	Large firms	Small firms
Technological level		
Usefulness		
Core	-0.2967698 (0.1060038) ***	0.4722439 (0.4795563)
Self-forward citations	-0.8412189 (0.2835086) ***	2.341526 (1.179064) **
Technological value		
Forward citations	0.6959381 (0.1091733) ***	-0.8979599 (0.5892663)
Scope		
Claims	0.2227023 (0.1265621) *	2.263676 (0.4632283) ***
Generality	0.2061579 (0.067741) ***	0.4148866 (0.289572)
Innovativeness		
Backward citations	0.1218969 (0.1096104)	2.017469 (0.8022052) **
Originality	-0.097917 (0.1411052)	-1.327827 (0.3190147) ***
Firm level		
Market share		
Market share	-1.742353 (0.5329053) ***	14.64449 (4.1053) ***
Industry level		
Competition		
Competition	-1.461507 (0.2469785) ***	-3.637967 (2.193422) *
Control		
Technological control		
Inventors	-0.0254704 (0.2493178)	-4.872622 (1.901167) ***
Self-backward citations	0.0115565 (0.152775)	-2.460021 (0.6478733) ***
Filed year	0.0208481 (0.0119298)*	0.1223165 (0.0615035) **
Firm Control		
US firm	-0.1935805 (0.0732615)***	-0.2238792 (0.6319144)
Statistical data		
N	3521	101
Log pseudo-likelihood	-1779.5909	-33.56352
Pseudo R2	0.067	0.4062

Table 7. Probit estimation for both large and small firms

Notes: ***, **, and * represent that the coefficient is statistically significant at 1%, 5%, and 10%; robust standard error of the coefficients are in parentheses patents, namely numbers of backward citations and originality. Note that the coefficients of both the variables for large firms are not statistically significant, which does not provide any evidence. This can be caused by a number of factors. The first possibility is that there is actually no correlation between the innovativeness of a patent and a large firm's willingness to license, and therefore the coefficients are not statistically significant. The second possibility is that the proxies of backward citations and originality fail to capture the innovativeness of a patent, so these variables failed to influence the licensing decision of large firms. The third possibility is that competition in the technology market due to the presence of multiple technology holders forces large firms to license innovative patents (Arora and Fosfuri, 2003). In this case, even if the originating patent holder does not license, the other technology holders will, thus motivating the originating patent holder to license. On the other hand, the empirical result of these variables for small firms suggests that they are less willing to list highly innovative patents on the market. Such reluctance may be caused by their flexibility in organizational structure, which gives them an advantage in competing in the product market, and results in a high rent dissipation effect.

The third hypothesis claims that the larger the market share that a firm holds in a particular technological class, the less likely it is that the firm will be willing to license its patents belonging to that technological class, and the empirical result agrees with this claim. The coefficient of the variable market share for large firms is negative and statistically significant at the 1% level, which means that a large firm is more willing to license its patents if they belong to a technological class in which has a small market share, because the rent dissipation effect would outweighs the revenue effect should the firm decides to license. Additionally, the coefficient of market share for small firms is positive and statistically strongly significant, which shows that small firms have an opposite licensing propensity to the large firms. When a small firm has a large market share, it becomes more willing to license its patents because it may find it difficult to defend this market share in the long run due to its inferior resources compared to competitors.

As a result, such a firm may have a different market strategy than a large firm; it aggressively engages in technology licensing and transforms its source of revenue from the product market to the technology market. On the other hand, when a small firm has a small market share, it tends to be less inclined to license the corresponding patents. One reason for this is the inferior quality of the patents in question, which may be unattractive to potential licensees. Therefore, in order to lower expenses, a small firm may decide not to make their patents available on the market since this incurs a non-trivial listing cost.

The fourth hypothesis states that the higher the intensity of competition in the product market, the higher the willingness of a large firm to license its patents. This is supported by the probit estimation since the coefficient of the competition variable is negative and statistically significant for large firms, while a lower value of the competition index represents a more intense competition. Recall that Fosfuri (2006) demonstrate the inverted U-shaped relationship between the rate of technology licensing and the number of technology holders, which means the rate of licensing increases with the number of technology holders until the number of holders has reached a certain value. However, this non-linear relationship only holds true for actual licensing activities which focus on the demand side of the market. In this empirical result, the linear relationship between a firm's willingness to license and competition intensity does not conflict with the above because it applies to the supply side of the market; even if the number of technology holders has reached a certain value, a firm's propensity to license will not decrease. In other words, that relationship in the supply side is monotonic. On the other hand, the coefficient of the competition variable for small firms is statistically significant and even more negative than that of large firms. It demonstrates that small firms are more sensitive to competition intensity in the industry and rejects the claims made by Fosfuri (2006) that small firms face a less intensive tradeoff between the revenue and rent dissipation effects.

Besides the above mentioned variables that support the hypotheses, the remaining variables also provide some interesting results. The first one is the technological value of a patent. Although the coefficient for forward citations for small firms is not statistically significant, that for large firms is positive and statistically significant at the 1% level, which demonstrates that large firms are more willing to license patents with higher technological value. This result agrees with the empirical studies by Gambardella et al. (2007) and Palomeras (2007). They explained that patents with high technological value create more technological opportunities and are attractive to potential licensees. At the same time, these patents might not be internally developed. As a result, the revenue effect outweighs the rent dissipation effect, and the profitability provides incentive for the patent holder to license.

Secondly, observe that the two variables for scope generally have the same results. The coefficients of the number of claims for both the model for large firms and small firms are positive and statistically significant, which shows that firms are generally more willing to license patents with a larger scope. In particular, the coefficient of the small firms is a lot larger than that of the large firms, shows that he licensing decisions of small firms are particularly sensitive to the patent scope than are those of large firms. The coefficients for generality, on the other hand, are both positively correlated to a firm's willingness to license, although only that for large firms is statistically significant.

The next two variables are the number of self-citations made and the number of inventors, where both are technological controls. The coefficients for both are not statistically significant for large firms, and are both negative and significant for small firms. This result demonstrates that small firms are more willing to license patents with a lower number of self-backward citations—which are more innovative and less related to the technological core of the firm—and have fewer inventors. Another important variable is the filing year of the patent, the coefficients of which are statistically significant for both large and small firms. Note also that the values of the coefficients are very low, which means that the firms are more willing to license recent patents, but the filing year is generally not an influential factor. Finally, the firm covariate of USfirm is negatively correlated to the propensity to license for large firms, meaning that large firms without business activities in the United States have a high willingness to license. This coefficient for small firms is; however, not statistically significant and does not show anything useful.

Chapter 6
Conclusion

This paper answered the research question "What are the differences between large firms and small firms when making licensing decisions?" In line with the revenue versus competition framework (Arora and Fosfuri, 2003) - assuming that profit is the only driver behind licensing and considering only firms with commercialization capabilities - this empirical study shows that large firms weigh the rent dissipation effect higher than revenue effect. At the technological level, large firms are less willing to license patents that are useful to them. At the firm level, they are more inclined to license patents that they have commercialized in areas where they have a smaller market share. Lastly, at the industry level, they have a higher propensity to license patents within industries with more competitive markets.

On the other hand, small firms see the revenue effect as being more important than the rent dissipation effect when making licensing decisions. Therefore, although taking on the risk of suffering from the rent dissipation effect, they are more likely to put patents that are useful to them on the market. At the firm level, the market share of a small firm in the product market is positively correlated to the willingness to license a patent that the product is embodied from. In other words, the larger the market share of a small firm, the more likely it would place the patent on the market, as it may find it difficult to maintain its large market share in a long run, so strategically it aims to change its source of revenue from the product market to the technology market. Whereas, when its market share is small, it may be caused by its inferior technologies, which are not attractive to the potential licensees. Therefore, the firm may not even bother to place the patents on the market since the listing costs may not be a trivial amount for it. Finally, at the industry level, small firms are also more inclined to license patents in industries with high competition intensity, which is the same as large firms.

Meanwhile, this paper also unveils some interesting results. First, while innovativeness of a patent is not an important factor in making licensing decision for large firms, it is negatively correlated to small firms' willingness to license. One possible reason is that small firms are more flexible in their organizational structure, which gives them an advantage in competing in the product market, and hence lower their willingness to license. Second, the technological value of a patent is positively correlated to the willingness to license for large firms. Gambardella et al. (2007) has actually showed that the economic value of a patent is positively correlated to both the willingness to license and actual licensing activities of firms of all sizes. Such willingness can be driven by the existence of multiple technology holders, which forces the large firms to license valuable patents (Arora and Fosfuri, 2006). Third, although small firms are more sensitive to scope than large firms when making licensing decisions, both large and small firms are more willing to license patents with broader scope. The reason is that the larger the scope of a patent, the stronger the protection, and the more technological opportunities it creates, thus resulting in a higher revenue effect, which is an effect that all firms rate highly.

This study also encountered a few limitations. First, the sample size of patents from large and small firms is uneven. One reason is that the online technology market has a listing cost, which may be non-trivial for small firms. However, it also reflects the realistic situation in the market for technology: such market is still underdeveloped and is inefficient in many aspects. Second, a number of restricting assumptions were made throughout the whole study, from theory development to empirical study. The major one is that it was assumed that profit is the only driver behind licensing activities. As a result, any strategic reasons for licensing, such as cross-licensing and setting standard for the industry, were ignored. Consequently, it is further assumed that all of the patents listed on the internet marketplace Yet2.com are there only for pure-revenue licensing.

This topic can be further explored in several directions. To begin with, this paper focuses purely on the supply side of the market. It would be; however, very interesting to consider the demand side along with the actual licensing deals, given the availability of data on these. Then, different type of licensing contracts, including exclusive licensing, non-exclusive licensing, and cross-licensing, could be differentiated, compared, and contrasted. Next, the different structures of licensing contacts can also be analyzed, such as per-unit royalties and lump sum royalties. Finally, although this paper includes patents across all industries, it does not separate the patents by industry due to the restrictions of the sample size. Notice that the nature, structure, and characteristics of different industries can vary significantly. Therefore, should the opportunity arise in the future, it would be very useful to compare licensing decisions and characteristics at different levels across all industries.

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