Research Policy 42 (2013) 315–325

Contents lists available at SciVerse ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

# General technological capabilities, product market fragmentation, and markets for technology

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ARTICLE INFO

*Article history:*
Received 16 September 2011
Received in revised form 28 May 2012
Accepted 9 August 2012
Available online 6 September 2012

*Keywords:*
Markets for technology
Licensing
Generality
Market fragmentation
Software

ABSTRACT

The combination of a firm capability (i.e., ability to generate general purpose technologies) and a market structure condition (i.e., fragmentation of downstream submarkets) may encourage licensing in an industry. That is, the probability of licensing should increase when product markets are fragmented and technologies support general purposes. Evidence consistent with these predictions emerges from a 1993 to 2001 panel of 87 firms that owned at least one U.S. software security patent between 1976 and 2001. The analysis uncovers some fundamental characteristics of how external knowledge exploitation functions; in particular, technology markets thrive when product markets are fragmented and firms have the capability to produce general technologies.

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## 1. Introduction

The commercial exploitation of knowledge is a main tenet of knowledge management theory (Argote et al., 2003; Teece, 1986), for which the exploitation of *external* knowledge—particularly in the so-called market for technology—is critical. From 1980 to 2003 in the G8 countries, technology royalty payments and receipts increased annually by an average of 10.7% and reached an annual volume of approximately US$190 billion in 2003 (OECD, 2006). Case study evidence also has stressed the increasing importance of business models that focus on the external exploitation of knowledge (Arora and Gambardella, 2010; Gans and Stern, 2010).

A mainstream line of research generally follows a classical Williamson's framework that hinges on the interplay between environmental transaction costs and licensing decisions (Arora and Ceccagnoli, 2006; Gans et al., 2002, 2008). However, recent contributions have established some clearer roots in firm-based research (Lichtenthaler, 2010; Cassimon et al., 2011; Kani and Motohashi, 2012; Fosfuri, 2006; Gambardella et al., 2007; Lichtenthaler and Lichtenthaler, 2009) and shifted the focus from exogenous conditions in which firms decide to license to firm-based determinants of licensing. In this context, we argue that an important determinant of licensing is the firm's capability to produce general-purpose technologies (GPTs; Bresnahan and Trajtenberg, 1995; Rosenberg, 1976) that can embrace many different product market applications (e.g., Bresnahan and Gambardella, 1998; Maine and Garsney, 2006; Von Hippel, 1994). In contrast, a dedicated technology may be perfectly suited for the application for which it is created, but it is not very useful for other applications.

The central role of GPTs for knowledge exploitation is evident in comments by the CEO of Peregrine Pharmaceuticals (www.peregineinc.com), who acknowledged that the company's "strategy for clinical development is designed to maximize the licensing potential of our *broad* platform technologies [that] gives us the ability to license and collaborate with many partners" (Business Wire, 2000: 12). An increasing number of firms similarly recognize the importance of GPTs (Gambardella and McGahan, 2010; Palomeras, 2007; Thoma, 2009), which can facilitate licensing without encouraging product market competitors (Arora and Fosfuri, 2003). Therefore, we consider an environmental condition that makes the ability to produce GPTs valuable: when downstream product markets are fragmented in different subniches, licensors can issue licenses to other firms that operate in market niches in which they do not compete directly, though that scenario requires the licensor to develop GPTs that can support distant applications.

We provide empirical evidence for this claim by studying the security software industry (SSI), a technology-based industry in which innovation plays a major role and that exhibits a clear vertical distinction among the market for SSI algorithms, the core technology of a SSI products, and markets for SSI products or services. Security algorithms also exhibit different degrees of generality. Those that are more specific to particular domains tend to be more effective in their realm but not applicable to many other

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http://dx.doi.org/10.1016/j.respol.2012.08.002

domains (The Economist, 2007). Moreover, SSI firms often patent their new software algorithms, which refer to specific technology classes and allow for greater precision in technology proxies. Our regressions predict the hazard that a firm will sell its technology from the beginning of the technology market in SSI, using a 1993–2001 panel data set. We find that the probability of licensing increases with downstream product market fragmentation and the generality of the licensor's technology, and that these two factors reinforce each other.

Our article therefore offers two main contributions. First, we contribute to literature on knowledge management, especially the stream dedicated to external knowledge exploitation (Argote et al., 2003; Lichtenthaler and Lichtenthaler, 2009). Within this realm, we focus on the role of firm-based determinants. For example, Fosfuri (2006) notes the role of firm market shares in a product market, Gambardella et al. (2007) consider firm size. We introduce the importance of GPT capabilities (Winter, 2003) and show that they can explain most heterogeneity in licensing outcomes. Second, we stress an important link between technological capabilities and downstream industry structure. In this respect, our finding replicates a classical theorem of the capability-based view that highlights the co-evolution of firm capabilities and environmental conditions (Argote et al., 2003; Sorenson, 2003).

In the next section, we provide a literature review, followed by our theory. We then describe the major features of SSI and present our data and empirical evidence. We conclude with some implications and further research directions.

## 2. Theory

As Teece (1986) has established, knowledge management studies should involve not only how to capture value from innovation but also, and more precisely, which conditions make external exploitation (i.e., technology licensing) more appropriate than internal exploitation (i.e., technology embedded in final products). Early economics research focused on the role of transaction costs in shaping technology markets. In particular, transaction costs encompass the search costs of finding a partner, fear of opportunism, and lack of valid knowledge protections (Cockburn et al., 2010). To solve the transaction cost problem, Arora and Ceccagnoli (2006), Hall and Ziedonis (2001), and Gans et al. (2002) suggest stronger intellectual propriety rights (IPRs), such that firms may be more likely to sell their technologies if IPRs are well defined. In contrast, if IPRs are weak, firms can earn rents from technology only by incorporating it into their own final products (McGahan and Silverman, 2006; Dushnitsky and Klueter, 2011).

Management scholars extend the IPR notion by considering how firm characteristics, such as market share, size, and human resource strategies, might influence their ability to exploit knowledge externally (Fosfuri, 2006; Gambardella et al., 2007; Lichtenthaler, 2007). These contributions reflect a classical approach to knowledge management theory that highlights two important facets (Argote et al., 2003): firm capabilities and their fit with some exogenous feature (e.g., IPR context). We base our theory on a particular capability that explains heterogeneity in firm licensing behavior. According to Helfat and Winter (2011), a capability arises when a firm has the ability to perform a particular activity as an intended purpose with patterned behavior. Capabilities are therefore a key dimension of firm heterogeneity and a source of competitive advantage. In turn, a repetitive, recognizable pattern of interdependent actions, involving multiple actors—also known as an organizational routine—is the main mechanism for generating capabilities (Feldman and Pentland, 2003). In our study context, we focus on a firm's capability to generate GPTs (Bresnahan and Gambardella, 1998; Palomeras, 2007; Thoma, 2009); in other words, we assume that firms differ in their R&D organizational routines and that these differences generate heterogeneous capabilities for producing GPTs.

We focus on the interplay between these capabilities, with their underlying routines, and the level of downstream market fragmentation of an industry. In defining downstream market fragmentation, we follow Klepper and Thompson (2006): Industries can be differentiated along various dimensions, such as the services they provide, the customer segments they target, or the geographic areas in which they operate. The more an industry is segmented in different submarkets, the less homogenous it is, and the more the firm's behavior and performance depend on the dynamics of the specific submarkets in which it operates.

We therefore develop a framework in which we assume that firms can own GPT capabilities or not and can compete in fragmented or homogenous industries. For simplicity, we exclude the case of pure technology suppliers without products, an assumption that fits well with industries in which it is affordable to move from technology to final product (e.g., software). With our framework, we can compare changes in the probability of concluding a licensing deal for a dedicated technology versus a GPT, in homogenous and fragmented product markets, respectively.

We start with a homogeneous industry and a firm that has the capabilities to produce a dedicated technology. A dedicated technology is well suited for a specific application, but it requires significant adaptation costs to be applied to other domains. Therefore, the dedicated technology fits the application to a homogeneous market, and a potential licensee can use it with minimal adaptation costs. Consider a company that plans to enter the product market but does not have the technology to operate in it. The company has three options: not enter, enter by investing in the technology, or enter by buying the technology. The low adaptation costs of the licensed technology only affects the third option, by raising the odds of demand for a license rather than the other two options.

However, industry homogeneity implies that the licensor may be reluctant to sell its technology, because doing so would make the licensee a close product competitor.

Let us define the product market profits of the licensor as $\pi(N)$, where $N$ is the number of competitors in the product market. Then $\pi(N+1)$ represents the product market profits after it licenses to a licensee. Following Arora and Fosfuri (2003), licensing creates a new competitor (i.e., the licensee), and thus the product market profits of the licensor become $\pi(N+1) \leq \pi(N)$, where the inequality occurs because adding a competitor cannot increase the profits of incumbents. Arora and Fosfuri (2003) point out that $\pi(N+1)$ is also the largest revenue that the licensor can obtain from licensing, because it cannot extract from the licensee more than what the licensee earns in the form of product market profits. Thus, the licensor licenses if and only if $(1+\alpha) \times \pi(N+1) \geq \pi(N)$, or $\alpha \times \pi(N+1) \geq \pi(N) - \pi(N+1)$, where $\alpha$ is the share of profits of the licensee that the licensor earns through royalty rates for the license. The share of $\alpha$ depends on several factors, including competition across licensors in the technology market, the ability of the licensee to develop the technology in-house, other factors that might affect the bargaining power of the parties, and the strength of the IPR that protect the licensor from imitation. We leave these factors in the background. We also abstract away from several other factors that affect this process, such as whether the licensor licenses to others or the reactions of the other product market competitors that may also decide to license. These industry-level factors are discussed extensively by Arora and Fosfuri (2003). Moreover, there are several other reasons for licensing (or not) that we do not address here (e.g., Hellmann and Perotti, 2011). Rather, the intuition that we highlight, and that it is a key factor in the more general, industry-level model developed by Arora and Fosfuri (2003), is that given $\alpha$,

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