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Tesis Doctoral

THREE PERSPECTIVES ON THE SECURITY SOFTWARE INDUSTRY: RESOURCE PARTITIONING, REAL OPTION, AND GEOGRAPHY ISSUES

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TESIS DOCTORAL

Three Perspectives on the Security Software Industry: Resource Partitioning, Real Option, and Geography Issues

(Tres Perspectivas sobre la Industria de Software de Seguridad: Recursos Particionados, Opciones Reales, y Asuntos Geográficos)

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to Attila, Betsabé, Katalin, Keán

and to the memory of István Sebrek

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RESUMEN EN CASTELLANO

Por medio de la presente proporciono un resumen sucinto de mi tesis doctoral. El título de la disertación es *Tres Perspectivas sobre la Industria de Software de Seguridad: Recursos Particionados, Opciones Reales, y Asuntos Geográficos.* Como el título lo implica, esta tesis doctoral consiste de tres artículos diferentes. Cada artículo está basado en una idea original.

El primer artículo “Los recursos particionados y las estrategias en los mercados tecnológicos” trata una pregunta importante de investigación aún no estudiada en la literatura de administración: cómo la estrategia de una empresa en los mercados tecnológicos está vinculada con la legitimidad empresarial. Para contestar esta pregunta de la investigación, he recurrido al marco de recursos particionados que explica como, en su lucha por sobrevivir, las organizaciones naturalmente evolucionan como especialistas o generalistas. Una organización generalista tiene un espacio amplio de recursos, y de este modo implementa una estrategia de producto que intenta mantener una oferta diversificada de productos en varios huecos en el mercado; por el contrario, una organización especialista cuenta con un espacio estrecho y enfocado de recursos, y aplica una estrategia de productos que consiste especializarse en un solo hueco del mercado. Por lo tanto, este artículo plantea la pregunta de cómo la postura de una empresa en el espacio de recursos condiciona su papel de comprador y/o vendedor en los mercados tecnológicos. En el marco teórico, el modelo de recursos particionados es un instrumento adecuado porque se asume que la estrategia de productos de las empresas –

siendo el resultado de un proceso evolucionario – es fijo al menos en el corto plazo, y por consiguiente una fuente exógena de heterogeneidad a través de las empresas.

Los resultados sugieren que las organizaciones especialistas, i.e. las que siguen una estrategia estrecha de productos, son más activas como vendedores en los mercados tecnológicos comparado con las generalistas, i.e. las que compiten en varios campos de productos. Por otro lado, las generalistas recurren mucho más a las adquisiciones tecnológicas comparadas con las especialistas. Este trabajo destaca las facetas subestudiadas de la literatura de ecología poblacional, demostrando que el modelo de recursos particionados es un marco teórico que puede ser provechosamente extendido a otros ámbitos no directamente vinculados con las probabilidades de sobrevivencia de organizaciones. Este trabajo también añade algunos elementos novedosos a la literatura sobre los mercados tecnológicos, introduciendo un nuevo argumento de debate, como está demostrado que la estrategia de productos influye el papel empresarial en estos mercados tecnológicos. Precisamente, el vínculo hallado habla sobre una cadena directa de causación entre la estrategia de productos, el tipo de tecnología, y el papel organizacional en los mercados tecnológicos.

El segundo artículo se titula “Diversificación intra-industrial a través de los lentes de las opciones reales: opciones reales, portafolio de opciones, e incertidumbre en la Industria de Software de Seguridad, 1989 – 2003”. Esta investigación está estrictamente basada en el razonamiento de opciones reales que es una teoría que recientemente ha ganado importancia en el campo de la administración. La aplicación de la lógica del razonamiento de opciones reales puede permitir a las empresas que experimentan una gran variedad de oportunidades que les pueden proveer flexibilidad en la creación del conocimiento. En lugar de hacer una sola apuesta grande para capturar una oportunidad de negocio, el razonamiento de opciones reales puede permitir a las empresas financiar simultáneamente numerosos proyectos de I&D,

de ese modo las posiciona más favorablemente en los mercados existentes o potenciales. Usando opciones reales, con el gasto de los mismos recursos, más oportunidades pueden ser exploradas y la empresa es capaz de reducir los riesgos estratégicos de hacer un compromiso excesivo. En base de los previos trabajos académicos, examino en este trabajo como dos opciones tecnológicas distintas, patentes y alianzas estratégicas de tecnología afectan la probabilidad empresarial en la entrada a un nuevo hueco de productos.

La evidencia empírica de la Industria de Software de Seguridad demuestra que separadamente y juntos (como un portafolio de opciones reales), ambos tipos de opciones reales, patentes y alianzas estratégicas de tecnología, influyen positivamente la diversificación intra-industrial. Sin embargo, este último efecto positivo del portafolio de opciones sobre la diversificación intra-industrial está negativamente moderado por la incertidumbre medioambiental. El estudio reivindica varios puntos de originalidad. Primero, la importancia del enfoque de opciones reales está demostrado para explicar la diversificación intra-industrial que es uno de las estrategias más importantes en un ambiente Schumpeteriano. En concreto, se confirma que las alianzas estratégicas de tecnología y patentes tienen características de opciones y ayudan a las empresas a realizar sus inversiones bajo incertidumbre. Segundo, el estudio demuestra el papel de tener una estrategia de portafolio de distintas opciones activas, y como una estrategia de portafolio puede relacionarse con el nivel de incertidumbre. La conclusión es que una estrategia de portafolio es efectiva solamente si todas las opciones reales que lo constituyen están constantemente actualizadas. Como el costo de la actualización se incrementa con el nivel de incertidumbre, las empresas pueden encontrar extremadamente difícil el mantenimiento de un portafolio de opciones actualizadas.

Finalmente, el último artículo, “La selección de ubicación para la búsqueda de tecnología externa: el papel de los recursos en los derechos de las propiedades intelectuales upstream y downstream" pertenece a la rama de búsqueda de conocimiento y tecnología en la literatura de administración estratégica. De modo parecido al primer artículo de la disertación, este también está relacionado con los derechos de las propiedades intelectuales. Este artículo investiga empíricamente el papel de los recursos en los derechos de las propiedades intelectuales upstream y downstream y su influencia en la disimilitud espacial de la red empresarial en la búsqueda de tecnología externa. Específicamente, estudio cuánto las empresas comparten la amplitud de coincidencia geográfica en las ubicaciones de la búsqueda de tecnología externa, dadas las inversiones hechas en patentes y trademarks. Yo propongo que las empresas son capaces de influir en la intensidad de coincidencia geográfica en la búsqueda de tecnología externa con respeto a los competidores, es la función de los recursos en los derechos de las propiedades intelectuales upstream (patentes) y downstream (trademarks), que también pueden variarse en la dimensión de generalidad (en patentes) y diversificación (en trademarks). Al distinguir las competencias empresariales por el estoc de patentes, la generalidad del estoc de patentes, el estoc de los trademarks vivos, y la diversificación del estoc de los trademarks vivos, yo obtengo que todos los covariantes relacionados con los derechos de las propiedades intelectuales influyen el aislamiento espacial de la búsqueda de tecnología externa en mayor o menor grado.

La contribución principal del trabajo es que, aunque existe una literatura amplia en los canales de la búsqueda de tecnología externa, estos trabajos no están vinculados a consideraciones geográficas. Esa investigación proporciona uno de los primeros intentos de reunir los enfoques sobre la búsqueda de tecnología externa y los componentes geográficos de la estrategia empresarial. Adicionalmente, encuentro que la decisión estratégica sobre la selección de ubicación para la búsqueda de tecnología externa depende de los recursos de los derechos de las propiedades intelectuales upstream y downstream. La presente investigación añade también algunas contribuciones empíricas. Primero, un rasgo notable del estudio que involucra conjuntamente las adquisiciones y alianzas estratégicas de tecnología como fuentes cruciales de conocimiento externo y tecnológico para las organizaciones de negocio. Segundo, se aplica un conjunto de datos paneles que hace posible un estudio dinámico sobre los recursos empresariales en los recursos de los derechos de las propiedades intelectuales y patrones de ubicación, requerido por estudios anteriores.

En resumen, los tres artículos representan contribuciones fuertes a la literatura en comercio tecnológico, opciones reales y la geografía de la búsqueda de tecnología externa. El fondo teórico está conscientemente desarrollado, y la literatura actual está bien introducida. En cada caso intente prudencialmente seleccionar la metodología apropiada, por ejemplo el modelo de Poisson en el primer artículo, o el procedimiento de asignación cuadrático en el último artículo. Un rasgo común en todos los artículos de la disertación es el uso de conjunto de datos paneles que permiten la posibilidad de sacar resultados más confiables sobre las relaciones indicadas en las hipótesis. La industria aplicada es otro vínculo común en los artículos. La Industria de Software de Seguridad es un ambiente muy interesante porque es una industria de alta tecnología y con cambios rápidos – igualmente con las industrias de láser, semiconductor y biotecnología estudiadas extendidamente en la literatura de administración. Por consiguiente, las conclusiones alcanzadas sobre este sector industrial pueden tener más potencial de generalización en términos de los resultados alcanzados.

INTRODUCTION

My Ph.D. thesis work titled by *Three perspectives on the Security Software Industry: resource partitioning, real option, and geography issues* consists of three separate but highly overlapping papers. All three papers debate regularities in the Security Software Industry focusing on technology and innovation strategies with respect to external knowledge sourcing. The papers are all quantitative based studies making use of a novel, self assembled and highly detailed database. They, however, each has something different to offer and present in my opinion interesting and encouraging food for thought.

The first paper, "Resource partitioning and strategies in the market for technology", marries Organizational Ecology literature and Markets for Technology research in investigating the characteristics of demand and supply of the markets for technology. The organizational ecology literature is used to understand and model the process of resource partitioning. The research question that is addressed is how product strategy affects the role a firm plays in the market for technology. Following the resource partitioning approach, organizations are classified as specialists and generalists. Specialists and generalists differ in the breath of their product strategy, which is focused on a specific product niche for the former, while it is evenly spread across several product domains for the latter.

The second paper builds on the real options approach to markets for technology research. The paper titled "Intra-industry diversification through real option lens: real options, option portfolio, and uncertainty in the Security Software Industry, 1989 – 2003". This research combines diversification literature with technology partnering, and aims to understand the role of uncertainty in technology investments using a real option approach. Drawn from the previous scholarly work, the research question centers upon how two different technological options, namely patents and strategic technology alliances, affect the probability of firm entry in a new product niche.

The third paper is titled "Location choices of external technology search: the role of upstream and downstream IPR assets". The paper aims to add subtleties to the debate on external knowledge sourcing and the role of economic geography. Specifically, it contributes to the debate in the literature by looking at multiple firm characteristics and how these shape the overlap of technology search channels among rival organizations. Specifically, I study how much firms share the extent of geographic overlap in external technology search locations given the investments made in intellectual property-related firm resources. In particular I posit whether firms are able to influence the intensity of geographic overlap in external technology search vis-à-vis competitors, is a function of upstream (patents) and downstream (trademarks) IPR tools that can also vary along a generality (at patents) and a diversification (at trademarks) dimension.

With respect to my thesis work, my objective was to provide highly stringent investigations, to obtain robust results, and that each of the works contain novelty in one way or another. All the papers have a clear-cut structure embracing an abstract, introduction, theoretical background and hypotheses development, data and methods section, description of results, and conclusions.

FIRST PAPER

RESOURCE PARTITIONING AND STRATEGIES IN THE MARKET FOR TECHNOLOGY

ABSTRACT

This paper investigates how product strategy affects the role a firm plays in the market for technology. Following the resource partitioning approach, organizations are classified as specialists and generalists. Specialists and generalists differ in the breath of their product strategy, which is focused on a specific product niche for the former, while it is evenly spread across several product domains for the latter. We argue that a focused product strategy favors an active seller role in the technology market, but makes technology acquisition less appealing to firms. On the other hand, firms that pursue a broad product strategy are more willing to buy technology in the market, but are less active as technology sellers. To test our contention, we consider a population of 736 firms that have entered the Security Software Industry since its inception in 1989 till 2002.

KEYWORDS: resource partitioning, market for technology, security software

RESOURCE PARTITIONING AND STRATEGIES IN THE MARKET FOR TECHNOLOGY

1. Introduction

Legitimacy is a central tenant of the population ecology literature (Hannan and Carroll, 1992; Cattani, Ferriani, Negro, Perretti, 2008). Legitimacy unleashes the process by which organizations' access, defend and control vital resources, and therefore enhance their survival chances. How organizations reach legitimacy depends on the characteristics of the environment and on the types of pressures that it generates. Thus, in their quest for legitimacy organizations must employ tools and strategies that are idiosyncratic to the environment in which they compete.

Few works have analyzed how firms reach legitimacy in high-tech environments characterized by active technology markets, despite a recent literature that has well documented the emergence and importance of such markets in several high-tech industries (Fosfuri and Giarratana, 2010). For example, Athreye and Cantwell (2007) show that technology licensing payments and receipts have accelerated considerably since the 1980s, after being roughly constant between 1950 and 1980. Recent estimates point out that worldwide technology-related transactions are close to 200 billion dollars a year (Arora and Gambardella, 2010).

As a consequence, firms are increasingly familiar with the opportunities offered by such markets, and take them into full account when designing their overall technology strategies (Arora, Fosfuri, and Gambardella, 2001a; Gans and Stern, 2003; Laursen and Salter, 2006). Several are the reasons why corporations might want to actively participate in technology markets. Firms license their technology to others when they lack the complementary assets to profit from the innovation at full scale (Teece, 1986), and such complementary assets are costly to access (Gans, Hsu and Stern, 2002), when they want to establish their technology as the standard of the market (Garud and Kumaraswamy, 1993), when they attempt to control entry (Gallini, 1984; Rockett, 1990), and when there are competing technologies available (Arora and Fosfuri, 2003). Firms buy technology from the market when they lack the capability to develop it internally (Ceccagnoli et al., 2010), when either the intellectual property or the downstream product market are highly fragmented (Ziedonis, 2004; Cockburn, Macgarvie and Müller, 2010), when the technology is an established standard (Shapiro and Varian, 1999).

Yet, an important research question that has not been addressed so far is how a firm's strategy in the market for technology is intertwined with firm legitimacy. To theoretically address our research question, we resort to the resource partitioning framework (Carroll, 1985) that explains how, in their struggle for survival, organizations naturally evolve towards either specialists or generalists (Hannan and Freeman, 1977). A generalist draws on a broad resource space, and thus implements a product strategy that attempts to maintain a diversified, multi-niche, product offer; by contrast, a specialist relies on a narrow and focused resource space and applies a product strategy that consists of specializing in a single product niche (Sorenson et al., 2006). Therefore, in this paper we ask whether and how a firm's position in the resource space conditions its buyer and/or seller role in the market for technology.

Despite the lack of academic research, this is a rather relevant issue in the current business arena. For instance, a large company like Microsoft bought the ultrasonic 3D motion sensing technology from PDP, a designer and manufacturer of videogame products, when it entered the videogame market. Similarly, LEGO, a leading Danish manufacturer of toys, acquired the necessary technology from Digital Blue, a specialized developer of interactive youth electronics and software, to support its forehead in the electronic toy market.

These two examples suggest that choices made at the level of technology strategy ultimately depend on the product strategy pursued by the company, i.e. its position in the resource space. Our aim is to show that the separation of an organizational population in two distinct groups that rely on different resources and thus different product strategies helps explain a firm’s legitimacy and its role in the market for technology. In our setting, the resource partitioning model is a suitable tool because it assumes that firms’ product strategy – being the outcome of an evolutionary process - is fixed at least in the short term, and thus an exogenous source of heterogeneity across firms. Indeed, as argued by Sorenson et al. (2006), “firms cannot easily rewrite their organizational codes upon reaching advantageous positions”, thus the very same routines that sustain an advantageous product positioning are responsible of other organizational postures.

To investigate empirically the relationship between product and technology strategy, we draw on a population of 736 firms that have entered the Security Software Industry (SSI) since its inception in 1989 till 2002. SSI is a relatively recent segment of the software industry, and proves to be an interesting test-bed for several reasons (Giarratana, 2004): i) it is a technology-driven industry where product innovation plays a major role; ii) the industry population splits into specialist and generalist organizations as a consequence of the bimodal distribution of security software users (a relevant resource space in this industry); iii) SSI displays an active market for technology (i.e. about 15% of revenues in this industry come from licensing as shown by Hoover data from 2000).

The results we obtain suggest that specialist organizations, i.e. those that follow a narrow product strategy, are more active as sellers in the market for technology compared to generalists, i.e. those that compete in several product domains. On the other hand, generalists resort more heavily to technology acquisition compared to specialists.

This paper contributes to different streams of the organization literature. First, it builds upon the population ecology tradition that views generalists and specialists as two types of organizations that are better fitted to survive when resources are partitioned (Carroll, 1985; Dobrev, Kim and Hannan, 2001; Kim, Dobrev and Solari, 2003). This literature explains how a firm's positioning in the resource space affects its survival chances and, in the long run, industry structure. Although the choice of whether firms should draw on a wide range of resources or focus their activities has a clear impact on survival and performance, this choice also affects the development of codes and routines that are likely to govern firms' behavior in different strategic domains. We thus depart from the classical ecologist studies that address organization survival, by illustrating how positions in the product space, which are built to maximize survival options, condition strategies in the market for technology.

Second, our work shows that generalists and specialists occupy orthogonal positions in the market for technology, where specialists usually play the role of sellers and generalists that of buyers. Thus, our framework suggests that, at least in innovation-based sectors, markets for technology provide a means for relational exchanges that are beneficial for both types of organizations. A market for technology thus represents an important instrument to analyze how generalists and specialists create mutual interdependences that are more cooperative than competitive. This is a rather novel insight to the resource partitioning literature, which has only recently started to investigate the interaction between specialists and generalists, mainly from a competitive perspective (Swaminathan, 2001).

Finally, from a different tradition, scholars in industrial organization have studied the emergence and importance of markets for technology (Anand and Khanna, 2000; Arora *et al.*, 2001a; Gans and Stern, 2003; Arora and Ceccagnoli, 2006; Fosfuri, 2006). Although this literature has extensively analyzed the reasons firms might have to participate in the market for technology either by selling their technology or by buying available technologies, little work exists on the link between product strategy and technology strategy. Cesaroni (2004) argues that markets for technology help firm to diversify thereby suggesting a causal link between markets for technology and product strategy. We adopt a rather different approach here and theoretically argue and empirically show that are firms' positions in the product space that affect their role in the market for technology. We thus enrich this line of research by identifying a dimension of heterogeneity across firms, their product strategy, which explains firm position in the market for technology.

2. Theoretical background

Our theory grounds on some specific assumptions. The context of application is defined by those sectors in which the technology is an important determinant of the quality of the final product, and can be disembodied (from the products), evaluated independently and, in principle, sold separately (Arora *et al.*, 2001a; Mendi, 2007). Thus, entry in the downstream product market does not necessarily require the internal development of technological capabilities because such capabilities can also be accessed via arm's length arrangements. This is likely to result in high competitive intensity. These industries, like laser, semiconductors, biotechnology, coating, software, not only account for a large share of technology licensing transactions across firms, but also show a well-defined partition of the customers' resource space: sophisticated lead-users who demand products with the state-of-the-art technology available on the market, and one-stop-shop customers who need more standardized solutions and thus prefer product packages of average quality, which include post-sale services (Gambardella and Torrisi, 1998).

Granted this, the resource partitioning theory perfectly fits in this context because it formalizes the process of increased competitive intensity caused by crowding in a market characterized by a finite set of heterogeneous resources (Carroll, 1985). Competitive intensity causes an escalating war for resources (Carroll and Swaminathan, 2000) and promotes organizational adaptation (Dobrev *et al.*, 2001). To survive, organizations partition the market space: some attempt to secure a toehold over dense and more central resource spaces, while others focus on dominating narrow and peripheral resource areas (Kim *et al.*, 2003). Thus, the underlying selection process separates the organizational population into two main strategic groups: specialists and generalists (Carroll, 1985: p. 1272; Boone, Bröcheler and Carroll, 2000). Specialists can survive on a limited range of resources as they exploit them closer to full capacity. Instead, generalists draw upon a wide range of resources like, for instance, technologies, customers, employee skills and such, and thus benefit from increasing returns to scale and scope (Hannan and Freeman, 1977).

Prior works examining a number of industries have reported that specialist firms are present along with larger generalist organizations (Carroll, 1984; Swaminathan, 2001). Indeed, through resource specialization, the specialist can increase customer fidelity, respond quicker and better to customer needs, and strengthen product customization (Carroll and Swaminathan, 2000). This approach creates a stronger organizational identity that legitimates specialists and increases their viability, despite the disadvantage of locating far from the densest or most abundant resource areas (Carroll, 1985).

Population ecologists have typically distinguished generalists from specialists according to the breath of product offer in which they operate as this information is supposed to be highly correlated with the underlying resources (Dobrev, Kim, and Hannan, 2001; Freeman and Hannan, 1983). For instance, Sorenson et al. (2006) use the distribution of product offerings across 12 product niches to identify specialist vs. generalist organizations in the machine tool industry. Dobrev et al. (2002) use the min–max difference in engine power output to measure niche width in the automobile industry. Thus, a specialist operates in a specific niche and attempts to strengthen its position over this narrow resource space, releasing product up-dates and new product introductions in its established niche. Generalists are, instead, organizations that spread the offerings evenly across the product space (Sorenson et al., 2006). While specialists build legitimacy through their idiosyncratic position in the product space which earns them reputation, customers' loyalty and appreciation; generalists establish their identities via large size, achievement of scale and scope economies, and more generally efficiency gains.

Specialists and generalists are governed by different sets of codes, routines and organizational capabilities. Even if most organizations are borne as small, single-market firms, they differ from the beginning in several fundamental dimensions, like their founders, available resources, entry timing, internal structure, luck. Some firms attempt immediately to expand their boundaries and grow; others prefer to stay small and focused. These choices increase the difference in the routines governing the firms and in the resources they control. Because specialists display a strong single-niche orientation and have to maintain their product releases always updated in this narrow resource space, they develop routines by doing more of a particular activity (for instance, they accumulate a given technological expertise). This high degree of specialization, which helps establish identity and legitimacy, creates barriers for a specialist to migrate to other potentially attractive product niches. By contrast, generalists draw on broader resources to cope with a larger spectrum of customers' tastes and the underlying technological requirements. Thus, they end up developing and relying on different routines and capabilities. For instance, flexible marketing capabilities are crucial for generalist firms as they have to manage the simultaneous presence in several market domains

(Teece *et al.*, 1994). Generally speaking, generalists are more likely to be governed by those routines that make expansion and diversification easier.

In short, the process of resource partitioning implies that specialists and generalists ground their survival abilities on the control of different resource spaces, which lead to the establishment of different identities as sources of legitimacy. In addition, specialists and generalists differ substantially on the set of routines that govern them. As stressed by population ecologists, these differences are undoubtedly very important to explain firm performance and survival. Here, we contend that this source of heterogeneity across organizations helps to explain other behavioral differences across firms. Specifically, we suggest that a firm's product market strategy, which is the outcome of the resource partitioning process, explains its role in the market for technology. We argue below that because specialists rely on more specialized and narrow resources, they strengthen their identity and legitimacy by selling in-house developed technologies. On the contrary, generalists develop routines that allow them to expand and diversify, but are not good enough in generating the state-of-the-art technology required to enter in many dispersed product domains. Therefore, generalists buy externally available technologies more aggressively than specialists.

3. Hypotheses

Supply side of the market for technology

As specialist organizations offer a narrow portfolio of products in their established niche, they ground their identity and legitimacy on keeping always updated their offerings and releasing products with a high degree of customization to the idiosyncratic needs of their niche demand. In turn, this intense, but focused product activity allows specialist organizations to experience greater economies of learning and specialization. Both because of the greater learning opportunities and because of the need to match quickly customer’s requests and suggestions (Von Hippel, 1986), specialist firms develop a strong ability to continuously innovate around their product offerings in the established niche. In other words, a specialist builds up technological expertise and controls state-of-the-art technology, which might potentially have a large number of applications in several fields of an industry (Arora and Fosfuri, 2003).

However, those routines and capabilities that govern the generation of the improved technology are also responsible of the inability of the specialist to exploit it in other resource spaces. In fact, diversification and expansion in other product domains is rooted on different routines, which are not easy to develop in the short term because they are the result of both built-in differences and path-dependence. In addition, identity and legitimacy of specialist organizations rely on their narrow focus in the product space. Thus, even if they might be able to outreach their established niche, expansion and diversification can generate back drafts over the current identity of the company (Teece, 1986). These arguments suggest that licensing out becomes an attractive strategy because it generates financial returns and avoids risky investments in downstream markets that the firm might be unable to manage efficiently and that could also undermine its identity. By acting as sellers in the market for technology, specialists can obtain an important inflow of cash that helps alleviate their financial constraints (Gans and Stern, 2003) due to the small slice of the resource space they occupy (Carroll, 1985; Swaminathan, 2001). In addition, Lichtenthaler and Ernst (2009) have shown that aggressive technology licensing is instrumental to establish a reputation for being a reliable and state-of-the-art technology firm, which ultimately helps increase firm legitimacy and survival. Thus, licensing out is consistent with the overall actions and strategies that specialists implement to gain legitimacy and boost their survival chances.

Clearly, deliberate policy of technology sale can augment the competition in the product market. Either it might encourage entry of outsider de novo/de alio organizations in the own market niche of the technology seller, or technology licensing might help improve production efficiency of incumbents (Fosfuri, 2006). To offset profit dissipation, specialists that occupy focused and narrow resource space can sell the technology to a distant resource space without breeding new product competitors (Arora *et al*., 2001a; Arora and Ceccagnoli, 2006). Given their state-of-the art technologies and their accumulated expertise, specialists have also higher chances to find buyers in distant product niches, which do not want to compete with a very aggressive rival (Lichtenthaler and Ernst, 2009).

Generalists rely on orthogonal resources compared to specialists, so the arguments we develop below go in the opposite direction, and explain why generalists are not typically technology sellers. Because generalists rely on a broad resource space, they might not be able to produce cutting-edge technologies that might attract the interest of specialist organizations. As argued above, their routines and capabilities are tailored at facilitating firm expansion and diversification; however, they lack the ability to bring the technology to the highest level of sophistication.

Moreover, since specialists tend to own near-to-frontier technologies, only would-be or actual generalists could form the target buyers, for whom the level of the technical sophistication of the supplied technologies might be satisfactory. However, a technology sale might breed stronger competition in downstream product markets (Fosfuri, 2006). The basic resource-partitioning argument highlights that within a population of firms, generalist organizations compete with each other to occupy the lucrative center of the market (Carroll, 1985). Technology sale by generalists can cause more competition among generalist firms that directly leads to the saturation of resource space. This initiates a crowding process that may leave generalists in worse competitive position: either it decreases their survival chances by heightening competitive intensity or it triggers modifications in their product niches (Dobrev *et al*., 2001). Thus, it is unlikely that generalists sell technologies to other generalists.

These arguments lead to:

Hypothesis 1: Specialists sell more disembodied technologies in the market for technology than generalists do.

Demand side of the market for technology

Concerning the buyer role in the market for technology, first, notice that the partitioning process can directly make specialization and small size as equivalent categories (Boone *et al.*, 2000), implying, inter alia, no availability of pecuniary resources for technology outsourcing. Under such circumstances, technology acquisition can further decrease the resources that normally support innovative activities of specialist firms. By contrast, generalists, due to their larger size, are endowed with those slack resources, especially financial assets, which could be channeled towards the acquisition of externally generated technology.

Second, a specialist creates its identity and thus enhances survival chances by establishing a reputation of technology champion (Garud and Kumaraswamy, 1993). Such a reputation not only provides beneficial conditions for technology sale, like increased bargaining power and greater visibility to potential buyers in the market for technology, but it also facilitates the acquisition of financial resources from financial markets and venture capitalists. By contrast, purchasing disembodied technology might detract to an organization's reputation of excellence, weakening its identity, which in turn can subsequently limit its chances of survival.

Generalists, instead, do not face this tradeoff. Their identity is built around the breath of their product offer, their size, and the simultaneous presence in different niches. They are likely to develop capabilities, like marketing skills or production efficiency, which are complementary to the core technology. Purchasing off-the-shelf technologies does not detract to their reputation of providers of one-stop solutions, and instead allow them to focus on the sources of their competitive advantage. Indeed, as generalists serve a wider and more heterogeneous set of customers with a larger portfolio of different products, they rely on routines that increase efficiency and productivity but that have the problem of creating rigidities and inertia (Mezias and Mezias, 2000). In short, generalists become less able to push forward the technological frontier. Therefore, technology acquisition for generalists is convenient to substitute weak internal innovation capabilities (Tushman and Anderson, 1986).

Finally, the process of resource partitioning has also an implication for infringement-related intellectual property rights (IPRs) transactions. As Ziedonis (2004), among others, have suggested, in those dynamic, high-tech industries in which markets for technology are active, technology trade is sometimes the outcome of a problem of excessive fragmentation of IPRs. Because firms may infringe (or infringe) other firms' IPRs, they secure "the right to operate" by negotiating ex-ante and/or ex-post licensing agreements with several IPRs holders in the industry (Cockburn, MacGarvie and Müller, 2010). Specialists, that draw on a narrow, homogenous, sometimes isolated, resource space (Swaminathan, 2001), tend to release products that fall in a single niche and rely on well-defined technologies. Therefore, they are less likely to be at risk of infringing on patents held by other entities. Resource specialization decreases the level of potential IPRs fragmentation faced by a given firm and in turn its necessity to buy or secure "a right to operate". By contrast, generalists have stronger incentives to resort to in-licensing as an insurance strategy. Because generalists control central resources, they face a highly crowded resource environment, and they are more likely to infringe on other companies' IPRs. Thereby it becomes imperative to shield themselves from the threat of costly litigations and potentially high reputation backlashes (Grindley and Teece, 1997; Ziedonis, 2004).

In sum, we posit:

Hypothesis 2: Specialists buy fewer disembodied technologies in the market for technology than generalists do.

4. Data and methodology

The Security Software Industry

Our test bed is the Security Software Industry (SSI). This industry is a relatively new segment of the software industry, which has grown from world-wide sales of USD2.2 billions in 1997 to USD6.9 billons in 2002 (International Data Corporation 2000 and 2003). North America and Europe account for roughly 50% and 30%, respectively, of worldwide market share in 2002 (International Data Corporation 2003). SSI is a highly competitive, technology-based sector with an intense product innovation activity accompanied by short product life-cycles (Giarratana, 2004).

The industry displays an active market for technology; for instance, about 15 and 17 percent of revenues in this industry came from licensing of the software algorithms in 2000 and 2002, respectively, as shown by Hoover's data. From 1989 to 2002, the cumulative number of technology transactions undertaken by security software firms is over 400 (Source: Infortract Promt).[1] Thus, SSI reports those conditions that allow the resource partitioning process to unfold and make the application of our theoretical background meaningful: continuous product innovation, active technology market, a significant rate of entry and exit, which implies high competitive intensity. Most importantly, customers of this industry seem to polarize quite naturally around two categories: medium/low tech users that demand comprehensive security packages, prefer one-stop solutions and ask for a high level of

[1] Our data on SSI do not suggest that specialized technology suppliers, i.e., firms that sell technology but do not compete in the product market, is a relevant phenomenon here, as it is in industries such as chemicals, biotechnology or semiconductors (see Arora et al., 2001b). This implies that the majority of technology trade takes place among SSI firms with product market presence.

technological service and assistance; and sophisticated buyers that are not satisfied with standardized solutions, seek the best product quality in the market, and demand the state-of-the-art technology (Giarratana, 2004). This partitioning of the customers' resource space makes both generalists and specialists viable despite the strong competitive intensity of SSI. Indeed, generalists offer a broad product portfolio that covers several SSI niches (see more below about different product niches in this industry) and satisfies the needs of the vast majority of customers, i.e. those that demand standardized solutions; by contrast, specialists thrive by offering continuous updates and improved versions of their established niche, thus addressing the requests of high-tech, sophisticated customers.

Construction of the population sample

Our population sample is composed by all firms that have introduced at least one product in SSI till December 2002. Product introduction data were taken from Infotrac's General Business File ASAP and PROMT database (former Predicast) that, from a large set of trade journals, magazines and other specialized press (e.g. eWeek, PC Magazine, PR Newswire, Telecomworldwire), reports several categories of events classified by industrial sectors. This data source is the more recent version of the former Predicast database and was employed in various studies (e.g. Pennings and Harianto, 1992; Fosfuri, Giarratana and Luzzi, 2008). We have searched for all press articles that reported a "Product announcement", a "New software release" and a "Software evaluation" in SSI (SIC Code 73726) from 1980 to 2002. We found that the first product was introduced in 1989. From 1989 to 2002, we registered 736 different firms that have introduced 2,589 different products. According to their SIC code classification, these products are classified in six niches: Authentication-Digital Signature, Antivirus, Data and Hardware Protection, Firewalls, Utility Software and Network Security and Management (Giarratana and Fosfuri, 2007). Every attempt was made to ensure that the data collection was comprehensive in its coverage and cleaned from eventual product double-counting.

Once again resorting to the same Infotrac database, we have downloaded all the articles that report a licensing event under SIC 73726 (Encryption Software Sector). Carefully reading the abstracts, we have kept only those ones that were technology licensing contracts and removed articles not related to technology transaction (i.e. marketing and franchising agreements). As a final step, we assigned buyer (licensee) and seller (licensor) roles to firms. In SSI, technology trade is strongly related to the mathematical crypto algorithm which is the principal component of security software products; and whose level of sophistication might provide competitive advantage to the owner firm. Importantly, the crypto algorithm that performs the encryption and decryption processes is responsible for the quality of security software product in terms of the security level and the speed of mathematical calculations (Giarratana, 2004).

Dependent variables

We use two dependent variables. The variable *seller* captures a firm's presence in the market for technology as a seller. This time variant variable is equal to the annual number of contracts signed by a firm as a seller of technology in SSI. The variable *acquirer* measures a firm's presence in the market for technology as a buyer. It is time variant and equal to the number of contracts signed by a firm in a given year as a buyer of technology in SSI.

We offer below two examples for the transactions behind our core dependent variables. For instance, Entercept Security Inc. licensed its intrusion prevention technology to iPlanet so that iPlanet could embed it into its core product. The deal enabled iPlanet's users to get protected against intrusions, web sited defacement, data theft and misuse (Telecomworldwire, October 2001). Another illustration concerns the deal between

NeoPlanet and Compaq where the former had supplied its Viassary security technology to Compaq. Compaq's aim was to build in the Viassary technology into its Compaq Advisor product which enabled companies to communicate effectively with their customers through multiple digital touch points (PR Newswire, August 2001).

Independent variables: Generalists and specialists

As we discussed above, the population ecologist literature has typically distinguished generalists from specialists according to the breath of product offer in which they operate (Dobrev, Kim, and Hannan, 2001; Freeman and Hannan, 1983); thus, a specialist manifests itself in the market through a narrow product strategy and multiple product updates, whereas a generalist holds a large product portfolio. Organizational niche width has been used by several authors as a proxy for generalist vs. specialist organizations. For example, Dobrev et al. (2001) and Kim et al. (2003) measure niche width of an automobile producer in terms of the min-max spread of engine capacity across all models manufactured by a firm at a given point in time. Sorenson et al. (2006) use the distribution of product offerings across 12 product niches to identify specialist vs. generalist organizations in the machine tool industry. In all cases, variations across a single dimension (higher or lower niche width) capture differences across organizations along the specialist vs. generalist dimension.

Following the literature we thus computed the *Berry index* of dispersion of a firm's product portfolio; specifically:

$$\text{Berry}_{\text{it}} = \left(1 - \sum_{k=1}^{6} (R_{kt})^2\right) * 100$$

where R_{kt} is a ratio between the cumulative number of firm *i*'s products in the *k*th niche of SSI and the cumulative number of firm i' products in all niches of SSI at year t. As SSI consists of six major niches, *k* varies between one and six. By construction, the Berry index can vary between 0 (implying no differentiation) and 100 (denoting maximum differentiation).

The standard interpretation of this measure is that organizations showing high values of the Berry index are more likely to be generalists *vis-à-vis* specialists. Thus, a single measure captures both population groups. We believe that this standard interpretation of the Berry index (niche width) might be too coarse in our context. Indeed, a low Berry index does not necessarily correspond to a specialist firm. As our theory suggests, and data from SSI confirm, product versioning is a standard practice in this industry for those organizations that specialize in a particular niche and strongly rely on customization and user-driven innovation practices (Shapiro and Varian, 1998 and 1999). A low Berry index does not capture the high degree of product versioning or the practice of constantly releasing updates, which characterize this industry. We thus complement the Berry index with a second measure of product strategy, which is meant to increase our chances to depict better the phenomenon we want to study.

Our second measure of product strategy, that we label *versioning index,* is time variant and is equal to the cumulative number of new versions of the product niche that has spurred a firm's entry in the SSI. The entry product niche is crucial to new ventures because it is typically used to establish reputation and first mover advantages, which turn crucial under fierce market competition in the periods following entry (Kazanjian and Rao, 1999). Also, a post-entry niche specialization strategy occurs with more frequency in the same niche that served at entry (Debruyne *et al.*, 2002). We assume that those firms showing high values for the versioning index are more likely to follow a specialist product strategy.

To make our findings totally comparable with previous studies, we start by running a regression in which we only introduce the Berry index. We then run a regression with only the versioning index. Finally, we introduce both variables simultaneously.

As a further attempt to capture better our theoretical constructs, i.e. specialists and generalists, we also propose the use of two dummies, which are obtained by combining the aforementioned indexes. *Specialist Dummy* is equal to 1 when a firm shows up very high values of the versioning index (in the top quartile) and less than average values of the Berry index (less than the mean); *Generalist Dummy* equals to 1 if a firm shows up less than average values of the versioning index (less than the mean) and very high values of the Berry index (in the top quartile). Given that we have two continuous measures, the *Berry Index* and the *Versioning Index*, to construct these dummies, we faced the classical type I or type II error trade-off: using a criterion that spots a generalist (specialist) that is not a generalist (specialist), or that culls a generalist (specialist) that is a generalist (specialist). We opted to minimize the first type of error, and be less stringent on the second. It is worth to note that if we had used two very strict criteria in the dummy definition (top quartile and bottom quartile), results would have been even stronger (regressions available from the authors upon request).

Controls

We introduce several time variant and time invariant control variables to capture factors that might influence firms' technology strategies (and thus their likelihood to buy or sell technology in the market). First, we describe our time-variant controls. Experience in the market is captured by the number of years a firm is competing in SSI (*age in market*). This variable is the difference between year *t* and a firm's entry year. Although our sample contains a group of large ICT firms, it is mostly composed by small-to-medium sized, young firms. This feature involves that traditional time-varying measures of firm size (e.g. sales, number of employees) for such organizations are difficult to obtain. Following Giarratana and Fosfuri (2007), we proxied size by the stock of *trademarks* that the firm had registered at the US Patent and Trademark Office up to year *t*. Based on interviews with managers of SSI firms, Giarratana and Fosfuri (2007) conclude that "trademarks are a fairly good indicator of a firm's volume of activity". Moreover, Seethamraju (2003) detects high correlation between a firm's sales and its stock of trademarks. Logarithm is taken to correct any potential distortion caused by a small number of firms with an extensive stock of trademarks.

We also control for the effect of industry fluctuations. Using the Compustat database, we downloaded company sales data for all firms pertaining to the Software Industry under SIC Code 7372 for each year of the study period. The value of our *software industry sales* variable for a particular year is the sum of sales volume of all software firms listed in Compustat under SIC 7372 in that year (data given in millions of US dollars). We also control for the possibility a firm participates simultaneously on both sides of the technology market, as a buyer and a seller. Even if we do not analyze the survival hazard of sample firms in this paper, there could be firms that do not follow resource partitioning rules, apply mixed strategies, and at the end exit the market. Therefore, when we run our estimations for technology sale (technology purchase), we introduce the dummy variable *anteacquirer* (*anteseller*) that is equal to one if a firm has purchased (sold) a technology in the previous year, and zero otherwise.

Time invariant control variables capture for the effects of pre-entry conditions. First of all, to control for different industry conditions at the time of entry we employ a measure of organizational population density at the time a firm enters the market (*density delay*). This is a standard control in population ecology studies (Carroll *et al.*, 1996; Sorenson, 2000) that assume that initial competition conditions have lasting effects on organizational performance. Some scholars have emphasized the importance of preentry technological background on future strategy realization (Klepper and Simons, 2000; Klepper, 2002). Accordingly, we controll for a firm's technological capability, likely an important determinant of technology market participation in a science-based industry such as SSI, with the stock of a firm's patents granted at the US Patent Office (www.uspto.gov) at the year of entry (*entry patents*). Patent stocks have been used extensively in the innovation literature to measure technological capabilities (e.g. Henderson and Cockburn, 1994). We considered all patents granted in the US class 380 (Cryptography) and 705 that are the fundamental technological classes in SSI (Giarratana, 2004). We also introduce a firm's age at market entry to proxy scale and experience effects. Age (*entry age*) at entry is calculated as the difference between the entry year and the year of a firm's foundation.

Past literature studied the magnitude and sustainability of first-mover advantages (Lieberman and Montgomery, 1988). Early entrants might benefit from first-mover advantages through economies of learning, established reputation and the existence of switching costs that are common in the entire software industry (Torrisi, 1998). Accordingly, we construct a 1-0 dummy to reflect possible effects of an early entry on technology market strategies in SSI. The dummy variable is labeled *pioneers* and equals 1 if a firm entered in the formative period 1989-91, the first 3 years of the industry, and 0 otherwise. We insert a dummy variable that takes the value of 1 if the organization is a US firm, and 0 otherwise (*US dummy*). This is meant to smooth the possible distortion effect for non-US firms in the US Patent and Trademark database. Moreover, the US SSI market is the largest national market in the world, giving to local firms a potential advantage.

Following Ahuja and Katila (2001), we created a control variable that corresponds to the pre-sample value of the dependent variable (*entryseller* and *entryacquirer*). Such pre-sample information works as a heterogeneity control for unobserved differences in capabilities and strategic posture in technology markets. Failing to account for such unobserved heterogeneity can cause estimation problems like over-dispersion and serial correlation.

Finally, since the big increase in technology trade starts from 1999, we inserted year dummies for this period using 1989-1998 as the baseline. Table 1 provides descriptive statistics and Table 2 presents a partial correlation matrix for the variables covered in the analysis.

Insert Tables 1 and 2 about here

Estimation method

The dependent variables of the study, annual number of sold/purchased technologies, are count variables and take only non-negative integer values. The application of conventional linear regression models assuming homoskedasticity and normally distributed error terms can lead to biased estimates. A Poisson regression approach is appropriate to accommodate such data (Hausman, Hall, and Griliches, 1984; Henderson and Cockburn, 1996). Accordingly, we estimate the following regression model:

$$Y_{it} = \exp(X_{it}\beta + C_{it}\gamma)$$

where Y_{it} is the number of technology licenses sold or purchased in t, X_{it} refers to the set of measures of a firm's product market strategy, which is meant to capture its generalist vs. specialist orientation, and C_{it} is a vector of control variables. The above specification does not account for unobserved heterogeneity. To alleviate this problem, we followed Ahuja and Katila (2001), and Ahuja and Lampert (2001). These authors in both papers estimated Poisson regression models using the General Estimating Equation (GEE) approach which is meant to model longitudinal Poisson data with serial correlation (Liang and Zeger, 1986). A clear advantage of the GEE methodology is that it provides a better treatment for over-dispersion and serial correlation, often present in panel data sets (Liang and Zeger, 1986). Regarding limited-range dependent variables and longitudinal research designs, GEE produces efficient and unbiased parameter estimates when the dependent variable is highly correlated within subject (Ballinger, 2004).

5. Results and discussion

Table 3 and 4 present results for all models using GEE Poisson estimators reported with robust standard errors. The baseline models present the results by including only firm- and industry-level control variables. In addition to the controls, Model 1 incorporates the versioning index only, while Model 2 includes the Berry index only. In Model 3 we introduce both variables simultaneously. Finally, Model 4 employs our two dummies that, as explained above, identify firms that are more likely to be specialists and generalists, respectively, along with all control variables. Table 3 helps us to draw conclusions about the possible interaction between product strategies, as outcomes of the resource partitioning process, and a firm's positioning in the market for technology. Overall, these estimations support *Hypothesis 1*. First, notice that the estimate of the Berry index is negative and highly significant both when it is introduced separately and when it is inserted jointly with the versioning index. Thus, the larger is the niche breadth of a company the greater its supplier role in the market for technology. The parameter estimate of the *versioning index* is positive and statistically significant, thereby suggesting that those firms that release a larger number of versions and updates of their core product are more active technology sellers. These findings are further confirmed in Model 4 where the dummy for specialist is positive and statistically significant, whereas the dummy for generalist is negative and statistically significant.

Insert Table 3 about here

Looking at our controls, the negative and significant coefficient of the variable *density delay* implies that unfavorable conditions at the time of entry discourage firms to position themselves as sellers in the market for technology. The dummy variable for early entrants into the industry (*pioneers*) shows a positive and significant effect on the number of sold technologies. It underscores the possibility of first-mover advantages toward licensing-out for firms that have entered the SSI during the formative years of the industry. This finding buttresses former evidence that early entrants benefit in the long run from their first-mover positions through product reputation, lead time and network effects, access to existing customers and (psychological) switching costs (Gandal, 2001; Makadok, 1998). The *US dummy* variable exhibits negative and significant effect on the number of technology sales which points toward the international character of SSI. Namely, non-US firms can gain foothold on the security software market, where the US SSI is the largest national market, through resorting to technology sale whereby limiting the potential disadvantage of foreignness. The *age in market* variable is negative and significant, suggesting that new entrants, probably suffering from limited initial earnings by an incompletely developed customer base, need to resort more to license out their technologies. Larger firms tend to have a higher number of transactions in the market for technology, which is likely to be a simple size effect. The positive and significant sign of the industry sale variable is as expected, showing that technology sale is facilitated in a growing industry. Finally, the age of a firm at entry, pre-entry patents and technology out-licenses sale do not significantly influence a technology sale strategy.

Table 4 displays the estimation results of the GEE poisson models in which the dependent variable is the number of technology acquisitions by a firm in a given year in SSI. Results seem to corroborate *Hypothesis 2*. First, notice that the estimated coefficient of the Berry index is positive and significant, thereby confirming that organizations with larger niche width tend to buy more technology in the market. The coefficient for the versioning index in Model 1 and 3, while negative, is not statistically different from zero. However, our two dummy variables, Specialist and Generalist, are both highly significant and with the expected signs, positive for generalists and negative for specialists. Overall, these findings suggest that generalists are more active than specialists as buyers in the market for technology.

Insert Table 4 about here

Differently from above, only few control variables appear to be significant here. The positive and significant coefficient of the variable *density delay* implies that harder competitive industry conditions at the time of entry encourage firms to follow a technology purchase strategy. The negative and significant sign for *pioneers* demonstrates that early entrants do not purchase technologies. Size, measured by the stock of *trademarks*, enhances technology purchase, perhaps through the provision of greater financial latitude, but this is most likely a simple size effect. *Anteseller* is positive and significant in some of the estimations. This might capture for some firm-specific ability to operate in the market for technology. The coefficients of the rest of the control variables are not statistically different from zero. Finally, the estimated scale parameters do not indicate that overdispersion in the data is a serious concerned.

We have also performed several sensitivity tests to check the robustness of our findings. The results of these alternative regressions are shown in Table 5. First, Model 1 shows results using an alternative measures of the niche width (e.g. the cumulative number of niches in which a firm operates) and the versioning strategy (e.g. the average level of versioning in all the niches a firm has entered). Abusing terminology, we will call these measures again Berry index and versioning index, respectively. Second, we performed regressions with the same explanatory variables that we have used in Models 3 of Table 3 and 4, but lagged one period, that is, computed at t-1 (see Model 2 in Table 5). Third, to make sure that outlier observations do not bias our results, we excluded the six largest firms in terms of their product stock from the estimation (Model 3 in Table 5). In so doing, we omitted the most active firms pursuing niche product leadership, such as Aladdin (data protection), Checkpoint (firewall) and Symantec (antivirus) and firms with the broadest product scope, such as Peoplesoft, SUN Microsystems and Webtrends. In sum, the results of these robustness checks remain qualitatively unchanged and correspond coherently with the overall previous results.

Insert Table 5 about here
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6. Conclusions

Combining the population ecology tradition (Carroll, 1985; Dobrev, Kim and Hannan, 2001; Kim, Dobrev and Solari, 2003) and the stream of research on the market for technology (Anand and Khanna, 2000; Arora *et al*., 2001a; Gans and Stern, 2003; Cesaroni, 2004; Arora and Ceccagnoli, 2006; Fosfuri, 2006), the paper examines how the dynamics of resource partitioning condition firms' strategies in the licensing space. We have found evidence that specialists are more active sellers of technologies compared to generalists, while generalists tend to buy technologies more than specialists.

Our work highlights some understudied facets of the population ecology literature. First, we show that resource partitioning is a framework that could be fruitfully extended to other domains not directly linked to the survival chances of organizations. Additionally, we show how the market for technology is a mechanism that allows the exchange of complementary resources between generalists and specialists. Specialists give away technologies and receive back liquidity and reputation from generalists. Therefore, the partition of some resources (i.e. different customers) that creates the two groups of organizations does not imply the complete isolation of specialists and generalists into impermeable resource spaces. The evolution of organization towards specialists and generalists could create a reciprocal demand and supply of resources that are pivotal for their survival. Hence, not all the resources are partitioned. Specialist strategies and routines generate non-rival or abundant resources (i.e. technologies) that could be interchanged with another set of resources produced by generalists (i.e. liquidity, reputation).

Second, this work also adds some novel insights to the market for technology literature, introducing a new argument of debate. The current literature focuses on the determinants of out- and in-licensing, like, for instance, transaction costs, fear of competition, characteristics of the technology, risk sharing, and such. We show that product strategy influences the role of a firm in these markets. Precisely, the underlying link speaks for a direct chain of causation between the product strategy, the type of technology, and the role of the organization in the market for technology. Future research has at least two avenues. First, contract theory could analyze the incentive mechanisms, and thereof the expected outcomes of their implementations. In this framework, specialist organizations must design incentives that assure that innovations that are best-sellers in the market for technology are developed. Second, absorptive capacity and dynamic capability theory could advance our knowledge of how generalists imbibe technologies from a pool of extra-mural knowledge through arm's length agreements, such as licensing.

Our analysis offers some important take-away messages for managers and practitioners. Technology management is of prime necessity for firms in high-tech industries characterized by disembodied technologies. Consequently, business managers should be well aware of the importance of correct positions of their firms in the technology markets and the coherent use of those markets in relation to their companies' product strategic aspirations. This means fine-tuning the product and licensing strategies and, related, the need of an efficient coordination between product, marketing and R&D divisions. For example, the creation of an independent licensing/IPRs unit or team could strengthen the bridges among divisions, avoiding problems of mismatch among strategy timing, steps and order of decisions.

Particularly, a specialist organization has to pay continuous attention on the demand side of the market for technologies, spotting potential buyers with low threats of product competition and creating up-dated technologies that successfully hit the market. For example, potential benefits could be derived also by contracting patent writers who craft well-written, clear-scoped and so more visible patents. Generalists should be able to scan efficiently the supply side of the market for technology, developing competences like finding the more fitted technology for their use (i.e. ability to search and comprehend ad-hoc patents in available datasets), and adapting them quickly with in-house knowledge and routines. For both organizations, the presence of experts in IPRs laws, licensing negotiations, and contractual rules, reduces transaction costs and fully helps to capture the benefits of technology licensing.

This last point opens up an important contribution in terms of industrial policy. Our results indicate that a well developed market for technology (efficient IPRs granting process, rapid court cases for infringements) will help gaining legitimacy to the two groups of organizations. It makes possible the generation of additional revenue and technology reputation for specialists that control narrow resources. By the same token, it is a consequence of product portfolio strategies that allow generalists to build up one-stop-shop offers for customers with less-techy preferences. One related conclusion is that maybe the creation of a governmental agency that acts, at least for all the firms in an industry, as a technology stock exchange could reduce all the market costs and benefit all the participants.

It goes without saying that our results find application in industries with idiosyncratic features like the presence of disembodied technology, a market for technology without high transaction costs, and the partition of the customers in different resource spaces. These features make SSI an ideal setting for testing our hypotheses, but they also ask for additional evidence that sustains the generalization of our implications. Industries like lasers, biotechnology, conversion coating, and battery chemistry are all good candidates.

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Table 1
Simple statistics of variables

Independent variables		Mean	S.D.	Min	Max
Core variables					
1	Berry Index	11.30	21.83	0	80
2	Versioning Index	1.68	1.67	0	25
3	Generalist (Dummy)	0.15	0.36	0	1
4	Specialist (Dummy)	0.09	0.29	0	1
Time-invariant controls					
5	Density delay	146.17	113.84	3	424
6	Entry patents	2.07	14.58	0	335
7	Entry age	6.77	15.80	0	159
8	Pioneers	0.11	0.31	0	1
9	US Dummy	0.74	0.44	0	1
10	Entryseller	0.03	0.26	0	7
11	Entryacquirer	0.03	0.23	0	4
Time-variant controls					
12	Age in market	2.74	2.71	0	13
13	Trademarks	1.95	1.67	0	7.79
14	Software industry sales	100,702.80	32,397.12	8,845	124,000
15	Anteacquirer	0.05	0.21	0	1
16	Anteseller	0.05	0.21	0	1

Source. Our elaborations spawn from the use of various data sources that embrace Infotrac's General Business File ASAP and PROMPT, US Patent and Trademark Office, and Compustat.

Table 2
Bivariate correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1														
2	-0.03	1													
3	0.80	-0.17	1												
4	-0.17	0.65	-0.14	1											
5	-0.02	-0.02	0.01	0.03	1										
6	0.16	-0.03	0.15	-0.02	0.09	1									
7	0.20	-0.02	0.18	-0.02	0.13	0.40	1								
8	0.03	0.03	0.00	-0.04	-0.39	-0.05	-0.08	1							
9	0.00	0.03	0.01	0.03	-0.03	-0.03	-0.10	0.09	1						
10	-0.06	0.06	-0.05	0.09	0.14	0.02	0.01	-0.04	-0.02	1					
11	0.12	-0.04	0.15	-0.03	0.19	0.28	0.19	-0.05	-0.02	-0.02	1				
12	0.14	0.13	0.06	0.03	-0.58	-0.05	-0.08	0.40	0.04	-0.08	-0.10	1			
13	0.39	0.06	0.35	0.00	0.01	0.31	0.44	-0.03	0.14	0.06	0.16	0.06	1		
14	0.14	0.11	0.10	0.09	0.53	0.05	0.07	-0.38	-0.03	0.07	0.09	0.20	0.09	1	
15	0.43	-0.03	0.41	-0.05	0.05	0.16	0.19	-0.02	0.02	-0.03	0.13	0.04	0.25	0.12	1
16	-0.09	0.26	-0.09	0.26	0.16	0.00	0.01	-0.06	0.02	0.07	-0.03	-0.05	0.06	0.14	0.00

Correlations with an absolute value of 0.04 or more are significant at $p < 0.05$.

Table 3
GEE/Poisson regressions on the determinants of technology licensing (seller role) for SSI firms, 1989-2002

	Seller									
	Baseline		Model 1		Model 2		Model 3		Model 4	
Constant	-9.599**	(1.701)	-10.046**	(2.078)	-9.652**	(1.784)	-9.099**	(1.666)	-9.195**	(1.295)
Core variables										
Berry Index			-0.042**	(0.011)			-0.031**	(0.008)		
Versioning Index					0.297**	(0.029)	0.286**	(0.031)		
Generalist (Dummy)									-1.900**	(0.472)
Specialist (Dummy)									1.565**	(0.148)
Time-invariant controls										
Density delay	-0.005†	(0.003)	-0.005	(0.003)	-0.004	(0.003)	-0.006*	(0.003)	0.005**	(0.002)
Entry patents	-0.006	(0.005)	-0.005	(0.004)	-0.009	(0.006)	-0.008	(0.006)	0.009**	(0.003)
Entry age	-0.010*	(0.005)	-0.012*	(0.005)	-0.009†	(0.005)	-0.008	(0.005)	-0.008†	(0.005)
Pioneers	2.934*	(1.193)	3.071*	(1.397)	2.822*	(1.218)	3.312*	(1.352)	1.430**	(0.494)
US Dummy	-0.167	(0.169)	-0.253	(0.200)	-0.352†	(0.187)	-0.421*	(0.194)	-0.214	(0.159)
Entryseller	0.226†	(0.129)	0.152	(0.127)	0.158	(0.127)	0.090	(0.126)	0.001	(0.151)
Time-variant controls										
Age in market	-0.597**	(0.183)	-0.543*	(0.213)	-0.724**	(0.189)	-0.849**	(0.216)	-0.080	(0.080)
Trademarks	0.138†	(0.073)	0.220**	(0.059)	0.122†	(0.062)	0.160**	(0.058)	0.214**	(0.043)
Software industry sales	6.1E-05**	(2.2E-05)	6.5E-05*	(2.6E-05)	5.7E-05*	(2.4E-05)	5.7E-05*	(2.4E-05)	3.5E-05*	(1.6E-05)
Anteacquirer	-0.883**	(0.281)	0.722	(0.474)	-0.479	(0.491)	0.078	(0.523)	0.189	(0.424)
Year dummies	Yes		Yes		Yes		Yes		Yes	
Scale parameter	2.20		1.82		0.99		1.19		0.67	
No. of firms	736		736		736		736		736	
No. of observations	3152		3152		3152		3152		3152	
Wald test ($\chi2$)	122.85		189.61		297.04		339.59		436.27	
Prob > $\chi2$	0.000		0.000		0.000		0.000		0.000	

† indicates p < 0.1. * indicates p < 0.05. ** indicates p < 0.01. Values in parentheses are heteroskedastic consistent standard errors.

Notes. Model 4 implies a robustness check using dummy variables for product strategies.

Table 4
GEE/Poisson regressions on the determinants of technology purchase (buyer role) for SSI firms, 1989-2002

	Acquirer									
	Baseline		Model 1		Model 2		Model 3		Model 4	
Constant	-8.104**	(0.889)	-8.697**	(1.095)	-7.892**	(0.866)	-8.382**	(0.977)	-4.913**	(0.462)
Core variables										
Berry Index			0.060**	(0.005)			0.060**	(0.005)		
Versioning Index					-0.147	(0.124)	-0.045	(0.113)		
Generalist (Dummy)									1.527**	0.386)
Specialist (Dummy)									-1.765**	(0.499)
Time-invariant controls										
Density delay	0.000	(0.003)	0.007**	(0.002)	0.000	(0.003)	0.007**	(0.002)	0.003	(0.003)
Entry patents	0.002	(0.002)	0.001	(0.003)	0.002	(0.002)	0.001	(0.003)	0.001	(0.002)
Entry age	0.003	(0.005)	0.005	(0.003)	0.003	(0.005)	0.005	(0.004)	0.002	(0.005)
Pioneers	-0.649	(0.758)	-1.115*	(0.454)	-0.661	(0.744)	-1.003*	(0.510)	-0.708	(0.686)
US Dummy	0.515†	(0.300)	0.199	(0.224)	0.522†	(0.296)	0.206	(0.224)	0.491	(0.307)
Entryacquirer	0.022	(0.252)	-0.036	(0.261)	0.023	(0.246)	-0.035	(0.259)	-0.052	(0.257)
Time-variant controls										
Age in market	-0.013	(0.150)	0.105	(0.086)	0.008	(0.147)	0.117	(0.090)	0.089	(0.131)
Trademarks	0.608**	(0.074)	0.277**	(0.067)	0.598**	(0.074)	0.276**	(0.067)	0.461**	(0.090)
Software industry sales	3.1E-05*	(1.3E-05)	1.8E-05	(1.3E-05)	3.0E-05*	(1.3E-05)	1.5E-05	(1.2E-05)	-1.2E-05	(9.0E-06)
Anteseller	0.143	(0.499)	0.754**	(0.255)	0.362	(0.443)	0.823**	(0.235)	1.197*	(0.507)
Year dummies	Yes		Yes		Yes		Yes		Yes	
Scale parameter	3.86		1.78		3.55		1.60		1.21	
No. of firms	736		736		736		736		736	
No. of observations	3152		3152		3152		3152		3152	
Wald test ($\chi2$)	419.55		1033.75		427.80		1155.05		351.94	
Prob > $\chi2$	0.000		0.000		0.000		0.000		0.000	

† indicates $p < 0.1$. * indicates $p < 0.05$. ** indicates $p < 0.01$. Values in parentheses are heteroskedastic consistent standard errors.

Notes. Model 4 implies a robustness check using dummy variables for product strategies.

Table 5
Robustness checks

	Seller			Acquirer		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Constant	-9.472**	-10.596**	-9.589**	-8.220**	-8.400**	-8.251**
	(1.780)	(2.063)	(1.688)	(1.103)	(1.249)	(1.000)
Core variables						
Berry Index	-0.267†	-0.023**	-0.038**	1.210**	0.031**	0.061**
	(0.138)	(0.007)	(0.009)	(0.121)	(0.004)	(0.005)
Versioning Index	0.293**	0.272**	0.274**	0.040	-0.199	-0.133
	(0.029)	(0.034)	(0.028)	(0.112)	(0.181)	(0.131)
Time-invariant controls						
Density delay	-0.005†	-0.004	-0.008*	0.001	0.004	0.007**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Entry patents	-0.008	-0.008	-0.006	-0.002	0.002	0.001
	(0.005)	(0.005)	(0.004)	(0.003)	(0.002)	(0.003)
Entry age	-0.009*	-0.009*	-0.009†	0.003	0.004	0.005
	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)
Pioneers	3.067*	3.631**	4.301**	-1.754**	-0.611	-1.160*
	(1.250)	(1.136)	(1.654)	(0.336)	(0.566)	(0.569)
US dummy	-0.361†	-0.279	-0.178	-0.162	0.325	0.186
	(0.189)	(0.187)	(0.146)	(0.202)	(0.238)	(0.232)
Entryseller	0.146	0.165	0.087			
	(0.126)	(0.125)	(0.130)			
Entryacquirer				0.184	0.102	-0.027
				(0.211)	(0.234)	(0.259)
Time-variant controls						
Age in market	-0.776**	-0.688**	-1.011**	-0.254**	0.003	0.124
	(0.194)	(0.180)	(0.192)	(0.090)	(0.102)	(0.096)
Trademarks	0.136*	0.135*	0.151**	0.364**	0.422**	0.278**
	(0.057)	(0.057)	(0.056)	(0.079)	(0.073)	(0.072)
Software industry sales	6.0E-05*	6.9E-05**	0.000**	2.6E-05*	3.3E-05*	0.000
	(2.4E-05)	(2.6E-05)	(0.000)	(1.3E-05)	(1.6E-05)	(0.000)
Anteacquirer	-0.292	-0.113	0.728†			
	(0.418)	(0.426)	(0.427)			
Anteseller				-0.020	0.745*	0.808**
				(0.261)	(0.326)	(0.255)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Scale parameter	1.06	1.15	1.32	6.89	2.69	1.66
No. of firms	736	736	730	736	736	730
No. of observations	3152	3152	3107	3152	3152	3107
Wald test ($\chi2$)	310.95	240.19	306.71	1681.4	824.13	1082.02
Prob > $\chi2$	0.000	0.000	0.000	0.000	0.000	0.000

† indicates $p < 0.1$. * indicates $p < 0.05$. ** indicates $p < 0.01$. Values in parentheses are heteroskedastic consistent standard errors.
Notes. GEE/Poisson regressions of the impact of product strategies on seller and buyer technology market strategies for SSI firms. 1989-2002.

SECOND PAPER

INTRA-INDUSTRY DIVERSIFICATION THROUGH REAL OPTION LENS: REAL OPTIONS, OPTION PORTFOLIO, AND UNCERTAINTY IN THE SECURITY SOFTWARE INDUSTRY, 1989 - 2003

ABSTRACT

Schumpeterian environments are characterized by fierce competition, rapid technological change, fragmented market shares and scarce scale economies. In such young, innovative and uncertain environments, a pivotal way to firm growth is intra-industry diversification; namely the entry into a niche that forms part of the same industry. Given the inherent uncertainty of these settings, we turn to real options reasoning (ROR) to study firm ability to adopt an intra-industry diversification strategy. Drawn from the previous scholarly work, we test how two different technological options, namely patents and strategic technology alliances, affect the probability of firm entry in a new product niche. Empirical evidence from the Security Software Industry demonstrates that separately and in unison (as a portfolio of real options), both types of real options influence positively intra-industry diversification. However, this latter positive effect of option portfolio on intra-industry diversification is negatively moderated by environmental uncertainty.

KEYWORDS: intra-industry diversification, technological real options, security software, Schumpeterian environment

INTRA-INDUSTRY DIVERSIFICATION THROUGH REAL OPTION LENS: REAL OPTIONS, OPTION PORTFOLIO, AND UNCERTAINTY IN THE SECURITY SOFTWARE INDUSTRY, 1989 - 2003

1. Introduction

An intriguing field of strategy study is the dynamics of relatively young, high-tech environments, such as the laser or biotechnology industries (Ilinitch, D'Aveni & Lewin, 1996; McKendrick, Jaffee, Carroll & Khessina, 2003). These industries, that usually the literature names Schumpeterian environments, often exhibit intense competition, fragmented market shares, rapid technological change, scarce scale economies, and little sign of consolidation around a few large players (Covin & Slevin, 1989; Giarratana & Fosfuri, 2007; Nelson & Winter, 1978; Schmalensee, 2000).

In this type of industries, a pivotal strategy that fosters firm growth and survival is intra-industry diversification. Indeed, intra-industry diversification not only allows a firm to grow by conquering market share in niches belonging to the same industry, but also it represents one pivotal way to create the potential for various sources of competitive advantage.

As past literature argues, intra-industry diversification can be a lucrative strategy yielding multiple benefits. For instance, it allows a more optimal use of factors of production (Li & Greenwood, 2004), mutual forbearance owing to implicit collusion by contacts at various segments (Golden & Ma, 2003). In addition, diversified incumbents might be better protected against new entrants by increased entry barriers (Lancaster, 1990), suffer less probability of exit (Giarratana & Fosfuri, 2007), enjoy positive demand effect (Siggelkow, 2003) and increased chance for a bundling strategy in case of positively correlated consumer preferences (Gandal, Markovich, & Riordan, 2005).

However, in such high-tech settings, an intra-industry diversification strategy would demand intense explorative investments in knowledge and technology. Typically, Schumpeterian industries are imbued with uncertainty. Thus, real options reasoning (ROR) appears as the most fitted approach to explain how the firm technological investment decisions could be effective in uncertain environments (Bowman & Hurry, 1993; McGrath & Nerkar, 2004). Compared to the net present value approach, the core idea of ROR places an accurate value on flexibility because firms instead of investing in a single, large project, fund simultaneously various ones, making possible a more thorough exploration of alternatives while reducing commitment and downside risk. Additional motivation for using ROR lies at the heart of option logic: a real option might secure a claim for the owner firm on future growth opportunities that appear in the business environment.

In Schumpeterian enviroments, two technological real options should be of highest importance: patents (Pakes, 1986; McGrath & Nerkar, 2004) and strategic technology alliances (Kogut, 1991; MacMillan & McGrath, 2002; McGrath & MacMillan, 2000; Reuer & Tong, 2005; Vassolo, Anand & Folta, 2004). This article tries to relate the investments in these two real options with the firm ability to pursue an intra-industry diversification strategy.

To investigate the research question, we resort to the Security Software Industry (SSI) which bears the features of a Schumpeterian environment (Giarratana, 2004). It is a young, dynamic and turbulent industry with high levels of uncertainty. We draw on a population of 921 firms that have entered the Security Software Industry since its inception in 1989 until 2003. Because it is composed of many sub-market niches, we could follow the patterns of intra-industry diversification of these 921 entrants.

We find that both technological alliances and patents are significant strategic tools for intra-industry diversification in SSI. What is more interesting, we have also investigated the joint effects of these real options. When firms apply a portfolio of both real options, the propensity for intra-industry diversification is also affected positively. However, this positive portfolio effect is negatively moderated by the level of uncertainty of the environment.

Our study claims several points of novelty. First, we show the importance of a real option approach for explaining intra-industry diversification that is one of the most important strategies in a Schumpeterian enviroment. Specifically, we confirm that strategic technology alliances and patents hold option characteristics and help firms to realize their investments under uncertainty. Second, we show the role of having a portfolio strategy of different active options, and how a portfolio strategy could interact with the level of uncertainty. Our conclusion is that a portfolio strategy is effective only if all the real options that constitute it are constantly updated. Since the cost of updating increases with uncertainty, firms could find extremely difficult to mantain an updated option portfolio. This means that the value of such a portfolio of R&D options decresases with the level of uncertainty. Finally, this article represents one of the few longitudinal large sample study in the field of intra-industry diversification in Schumpeterian environments in which ROR remains one of the most appropriate perspective.

2. Theoretical Background

In fast-moving, highly uncertain environments, real options reasoning (ROR) offers an appropriate tool to study firms' investments patterns. ROR is rooted in financial theories and offers a complementary approach to normative models of investments under uncertainty (Fama & French, 1992, 1993, 1995). A financial option contract provides rights but not the obligation to realize the investment. Later on, the purchaser of the option has the possibility to either buy or sell the underlying asset. Along time the uncertainty presented in the option may unfold facilitating firm decision on whether committing further investments. In the reverse case, the option expires but all that is lost is the price related to opening the option. As Mitchell and Hamilton (1988) have observed, one can establish the parallel between the organizational R&D option and the stock option. First, the price of the call option corresponds to the whole cost of the technology project. Second, the exercise price is related to the necessary additional investments committed by the firm to capitalize on the R&D investment when the investment decision was brought. Third, “the value of the stock for the call option is analogous in the R&D case to the returns the company will receive from the investment” (Mitchell & Hamilton, 1988: p. 17). However, McGrath and MacMillan (2000) illuminate how real options differ from the financial ones: “They cannot be valued the same way, they are typically less liquid, and the real value of an investment to one firm may differ a lot from its value to another firm”. Another marked difference is that the purchaser of the stock option can not exert a direct effect on the exercise price or the future price of the stock, “whereas the major purpose of the R&D option is to influence the future investment favorably, either by lowering costs or by increasing returns (Mitchell & Hamilton, 1988)”.

Applying ROR logic can allow firms to experience a greater variety of opportunities that may provide them flexibility in new knowledge creation. Instead of making a single big bet to capture a business opportunity, ROR allows firms to fund simultaneously a number of R&D projects thereby positioning them more favorably in existing or potential markets (Kogut & Kulatilaka, 2001; MacMillan & McGrath, 2002). Using real options, with the same resources to spend, more opportunities can be explored and the firm is able to reduce strategic risks of making commitments. What makes an option valuable and distinct from other organizational resources, according to Bowman and Hurry (1993) is that an option confers preferential access to an opportunity for investment choice – while not requiring a commitment to follow through - which might offer an advantage for the organization over its competitors. Realizing investments imbued with option logic, the investor firm can face a larger set of possibilities than were each exploratory foray to be a full launch. Under uncertainty it is a valuable strategy to follow, permitting the firm to expand the number of trials and simultaneously reduce the risk of making commitments. With parsimony in terms of the cost of learning, a range of promising technical directions can be explored at the same. Then, the firm keeps those options worthy of investment while it allows the remainder to expire.

An options approach allows a firm to realize exploratory investments in capabilities that permits it subsequent to the investments in options to enjoy performance heterogeneity (McGrath & Nerkar, 2004) and make the best response to market opportunities (Kogut & Kulatilaka, 2001). If it is so, real options might spur a foray into a new but technologically related technological area. The present study discusses intra-industry diversification focusing on new market niche entrance which strategy might be induced and explained by making resource commitments in technological options. The framework developed by this study considers patents (Pakes, 1986; McGrath & Nerkar, 2004) granted by firms and strategic technology alliances (Kogut, 1991; MacMillan & McGrath, 2002; McGrath & MacMillan, 2000; Reuer & Tong, 2005; Vassolo, Anand & Folta, 2004) realized by companies as real options. Each tool can be viewed as an option since they form a component of total firm value, can be described as specific projects and convey choices to the decision maker organization (McGrath, Ferrier, & Mendelow, 2004).

In many industries, a powerful way for firm growth is the entry into another, intra-industry and so technologically related subfield. ROR is an appropriate framework to study exploratory investments and intra-industry diversification as it integrates various strategy themes, such as resource allocation and investment, strategic positioning and organizational learning (Bowman & Hurry, 1993). Past literature argues that intra-industry diversification can yield multiple benefits which provide firms with competitive advantage over non-diversified firms. First, it allows a more optimal use of factors of production (Li & Greenwood, 2004). The deployment of organizational resources by the ROR logic furthers the realization of such efficiency gains, e.g. economies of scope since the average R&D costs of a technology and body of knowledge decrease as it is embedded into a new product dedicated to entry into a technologically related market niche. Second, among multi-niche players it may provide the possibility for implicit collusion elicited by contacts at various segments within a specific industry which is termed as mutual forbearance. Golden and Ma (2003) defines this phenomenon as “the ceding of control of one product or geographic market to a competitor in exchange for that competitor’s acquiescence in another market”. If firms posit sufficient resource endowments to demonstrate credible threat to each other, competitors might coordinate their activities which may lead to market power (Scott, 1982), reduced rivalry and increased returns (Baum & Korn, 1996; Gimeno & Woo, 1996) and decreased rates of entry and exit (Barnett, 1993; Baum, & Korn, 1996; Boeker, Goodstein, Stephan, & Murmann, 1997). Nevertheless, firms might not possess the necessary organizational capability to practice a mutual forbearance strategy (Golden & Ma, 2003), and specific conditions should exist to obtain pecuniary gains by the phenomenon (Li & Greenwood, 2004).

Third, another source of advantage for diversified incumbents might be captured by increased entry barriers (Lancaster, 1990). When a great many firms compete simultaneously in various niches, they enhance the saturation of those niches, thereby making the entrance harder. This effect holds even stronger against de novo newcomer organizations when initial sunk costs at entry are evanescent. In a high-tech Schumpeterian environment, the presence in multiple niches of the same industry reduced the hazard for firm demise (Giarratana &

Fosfuri, 2007). Similarly, as Dobrev, Kim and Carroll (2002) found, large niche width can be favorable in more unstable environments. Moreover, broad product offering may have a positive demand effect for seller firms because consumers might find it convenient to make their purchase on the idea of one-stop shopping (Siggelkow, 2003). In addition, positively correlated consumer preferences could yield a bundling strategy that might permit firms to garner greater profits (Gandal et al., 2005).

As real options, patents and strategic technology alliances might play an important role in the knowledge renewal and innovative process of the firm and contribute to their successful market-product adaptation process. However, the way they might contribute to diversification decision is disparate. To a great extent, patents are built on the firm's internal innovative capabilities, while strategic technology alliances are aimed to lay down a smoother pathway for learning and knowledge acquisition mechanisms from other organizations. At the organizational level, as March and Simon expound, many innovations result from borrowing rather than innovation (March and Simon, 1993; p. 209). Thus, external sources such as strategic technology alliances may be conducive to firms' innovation process. Internal resource endowments stored in patents are also essential compared with the infusion of knowledge through strategic technology alliances, as new skills often grow from combining existing forms of knowledge (Kogut & Zander, 1992; Teece, Pisano, & Shuen, 1997). Besides, as Hagedoorn and Schakenraad expound, patent intensity of firms may cause differences in recognizing technological opportunities, which is a beneficial ability in uncertain environments (Hagedoorn & Schakenraad, 1994).

3. Hypotheses

Intra-industry diversification by strategic technology alliances

To enter a new niche or a new line of business, firms need to do explorative research, with a scope well beyond that of current activities. Strategic technology alliances appear as expedient tools for such explorative undertakings for various reasons. Via strategic technology alliances partner firms are able to share risks, pool resources enjoying less investment commitments, realize gains by organizational learning and exhibit knowledge transfer. Moreover, alliances allow firms to select partners with complementary resources, thereby lowering the total investment cost. This creates the potential for greater synergy that presents opportunities for enhanced learning as well as the development of new capabilities (Harrison, Hitt, Hoskisson, & Ireland, 2001). Furthermore, Madhok and Tallman (1998) suggested that alliances where the partners had complementary resources had the highest probability of creating value.

Past literature in ROR emphasized the importance of technological (Kim and Kogut, 1996) and networking capabilities (Kogut and Kulatilaka, 1994) as strategic options that facilitate firm growth. By reason of the multiple benefits, technological alliances might have substantial potential value for new knowledge and technology development in turbulent and technologically vibrant Schumpeterian environments. Strategic technology alliances are such technology projects that represent a limited downside investment, giving a company a privileged position to launch a commercial product at some point in the future. These mechanisms are real options not only in terms of the legal assignation of contingent rights but in terms of the economic opportunities to expand and grow in the future (MacMillan & McGrath, 2002). To commit an expansion strategy to a new market or to a new market niche within the same industry, the value of such options is the greatest at these company maneuvers since any given firm is unlikely to possess the full repertoire of skills.

Diversity faced by the firm via strategic technology alliances may help against organizational ossification and cognitive simplicity, break rigidities in partnering firms and broaden a firm's knowledge base and decrease inertia. But even if a cooperation's practices are not seamlessly integrated, they may contribute to enrich mental maps, internal debate and the reasoning with new concepts and links explaining the dynamics of the business (Calori, Johnson, & Sarnin, 1994; Miller, 1993). Infusion of fresh knowledge via technology alliances can prove to be extremely useful in Schumpeterian settings where external conditions change and alternative responses are required. The phenomenon of competency trap may endanger the organization less as it adapts better to new circumstances and market opportunities inherent in Schumpeterian settings. Technological collaborations also further firms' search for new knowledge in distant contexts that may offer conducive ideas and insights to innovation through knowledge recombination (Rosenkopf & Almeida, 2003).

In summary, we predict that strategic technology alliances are conducive tools for firms to diversify from their core businesses within a Schumpeterian industry into new niches. These cooperations result in new skills, knowledge and technology that let the firm grow and expand into new market niches. This type of exploratory researches might involve the potential to foray into new scientific fields, increase the potential variance of returns. And it allows especially small firms to set high product innovativeness (Kotabe & Swan, 1995). The following hypothesis reads:

> *Hypothesis 1: In a high-tech, Schumpeterian industry, the stock of strategic technology alliances affects positively the firm propensity of intra-industry diversification.*

Intra-industry diversification and patent investments

Previous studies give proof of treating patents as real options. Pakes (1986), for instance, studied via option valuation patent holders' behavioral patterns to renew their patents or let them expire. McGrath and Nerkar (2004) explored firms' motivations to invest in a new option operationalized by investments in patents. They found that firms tend to take out patents in a new technological area if that area offers the firm the opportunity to grow (McGrath & Nerkar, 2004). Accordingly, the scope of opportunities of the new technological area inspires firms to appropriately adapt their R&D strategies and the associated investments favoring exploratory research into growth options (McGrath & Nerkar, 2004). For a new technological area, the investment into patents under the presence of potentially high variance in performance outcomes fits to ROR framework, since they might contain investment incentives using other approaches (Morris, Tesiberg & Kolbe, 1991).

Patents possess real options characteristics because they provide the opportunity to respond to future contingent events, like the later commercialization through capturing a favorable market opportunity which appears at intra-industry diversification. To grasp such windows of opportunity, patents are those assets that offer preferential access, thus the right for expansion. The patented technology is the subject of a better exploitation when it is applied to a new but related area, which might occur at intra-industry expansion. Exercised past patents might serve well for such a strategy, providing the claim to a technological base to create a sophisticated product which matches to customer needs and can benefit firms even in fierce competition.

Patents provide formal intellectual property rights (IPR) for the innovator thereby decrease the potential for expropriation and reverse-engineering. This allows even small-sized new ventures to invest profitably in knowledge-based products and services and then to appropriate it effectively at their market strategies. IPR protection for innovative knowledge is of vital importance in high-tech, Schumpeterian environments as small-sized firm is the dominant organizational form. Giarratana and Fosfuri (2007) documented that in a Schumpeterian industry, successful firm adaptation might depend on entry into new, proliferating niches. Such an intra-industry diversification strategy is supported if past patents are related to key technological classes of the industry. Thus, it is rational to suppose in a high-tech industry composed of technologically coherent subfields that patented technologies are intelligible and applicable in these new but highly related contexts, and provide impetus to entry. Since technological classes strategic for an industry can be selected ex ante with high precision, patents granted can be considered as strategic options, because “the more a firm knows about a key technology for a market, the quicker it should size the business opportunitiy” (Giarratana, 2008: p. 6).

Since in Schumpeterian environments fluctuations in external conditions occur with more frequency, wise firms might exert more resources and organizational commitment to enhance their adaptation and grasp growth opportunities. An appropriate strategy is to take out patents by the own efforts of the firm. A patent is created to efficiently protect around an innovation leading to a codified technology. The aftermath for firm strategy can yield lead time advantage, spur various downstream applications which lead to new product development. This intent toward technological renewal can become adequate responses for firm growth and successful market adaptation. Giarratana and Fosfuri (2007) buttress this conjecture showing that patent stock at entry into a Schumpeterian industry commands a higher probability of firm survival. In addition, patents are strongly correlated with new products (Comanor & Scherer, 1969). According to past research, the ability of taking out patents illustrates firm stature in the technical arena (Narin, Noma & Perry, 1987; Trajtenberg, 1990) and the level of technological capabilities (e.g. Henderson & Cockburn, 1994). This feature may benefit firms through increased reputation that does the firm a good turn when entering new niches at intra-industry diversification. Based on the above mentioned, we suggest that patents as real options support firm strategy at new niche entry within the same industry:

Hypothesis 2: In a high-tech, Schumpeterian industry, the stock of patents in the technological classes that are strategic for the industry affects positively the firm propensity of intra-industry diversification.

Intra-industry diversification and real option portfolio

Hereinafter, we raise the issue of the possible consequence of opening up simultaneously a number of heterogeneous technological real options on intra-industry expansion. Smart firms might apply diverse types of R&D initiatives to respond effectively to future challenges (MacMillan & McGrath, 2002). Similarly, articles on core competence argue that firms are better positioned for future growth by developing portfolios of skills and capabilities (Prahalad & Hamel, 1990). Indeed, with maintaining a wide and composite technological portfolio of real options, the firm has the opportunity to invest properly in better understanding the underlying scientific knowledge related to a new field.

A decision-maker using ROR can realize sufficient gains from the fact that real options are not independent investments but may reciprocally strengthen each other's effect (McGrath & Nerkar, 2004; Vassolo et al., 2004). Namely, the elements of the option portfolio interact and affect the value of other options. It is important to note that organizations investing in options are able to realize economies of scale and scope in terms of knowledge. Economies of scale can be grasped using an earlier real option when knowledge is replicated into a new option at a lower cost. Economies of scope can be also attained since knowledge may not be specific to a single R&D project and can be utilized in other explorative settings (Grant & Baden-Fuller, 2004). The options logic also suggests that options in the organization's technology portfolio are interrelated with each other, and realized by a logical sequence that exhibits features of a path-dependent cumulative process (Nelson & Winter, 1982). Relatedly, Vassolo et al. (2004) suggest that fungible capabilities are highly valuable for growth options and might lower the price for obtaining such options. A portfolio of heterogeneous options can increase such an effect as capabilities resulting from a specific type of option might be apt for redeployment in the other type of technological option.

Our argument centers upon the benefits that applying jointly, patenting and partnering in strategic technological alliances might breed. Knowledge embedded in patents essentially generates a body of codified knowledge which could be transmitted in a relatively complete form, and hence can be readily utilized in a strategic technology alliance. Patents also offer strong IPR protection on key knowledge and technologies by which a firm can (a) safeguard its investments in light of expropriation risk faced in R&D alliances (Ziedonis, 2004); (b) enjoy stronger bargaining position in the technology alliance, thereby increasing its productivity (Makhija & Ganesh, 1997). Additionally, patent stocks might make the firm more attractive in a process of alliance partner selection and therefore it promotes skill sharing and facilitates the search for partners with appropriate complementary resource profile (Sakakibara, 1997). On the other hand, knowledge acquisition via strategic technology alliances can spur patent creation.

In sum, pursuing simultaneously both strategies, portfolio owner firms are able to continually improve their competitive advantage because by investing in dissimilar options, a firm might avoid the development of narrowly based skills and might provide the possibility for the creation of a constantly updated platform technology. The outcome of this strategy is that a firm is more likely to diversify into new markets (Kim & Kogut, 1996). Therefore, our third hypothesis reads:

> *Hypothesis 3: In a high-tech, Schumpeterian industry, the ownership of a technological option portfolio consisted of both patents and strategic technology alliances affects positively the firm propensity of intra-industry diversification.*

The tension between uncertainty and real option portfolio

Even though building a technology portfolio of options provides the firm flexibility for intra-industry diversification, these benefits presumably would be lessened in highly uncertain periods of the industry. In a Schumpeterian environment, several types of uncertainty can erode the effectiveness of a technological option portfolio: (a) market uncertainty on costumer preferences (Sorenson, 2000); (b) uncertainty about the trajectory of technological development (Kim & Kogut, 1996); (c) competitive uncertainty due to high entry rates (Barnett & Sorenson, 2002) and the constant danger that these new entrants are equipped with valuable technologies and rich knowledge structure (Giarratana, 2004).

In periods with excessive uncertainty, the real option value derived from the joint application of patenting and technology alliancing could stifle. What triggers this effect, is the raising costs of maintaining an updated portfolio of technological options. Creation of new patents and network links generate increasing costs because firms are less able to predict the evolution of technological change and of the potential sample of partner firms as the global uncertainty increases. Accordingly, under such extreme circumstances, the application of a portfolio of technological investments might go beyond the carrying capacity of the organization, making extremely difficult to update both types of options. For example, firms can easily face organizational and financial constraints which limit their investment degree of freedom, at least in the short-run. Thus, we expect that the higher level of uncertainty generate higher investment needs that could bestow extra financial burden to firms.

As the Red Queen model postulates (Barnett & Hansen, 1996), organizational learning can be harmed when firms face many, varied cohorts of rivals, that is a remarkable feature of Schumpeterian industries (McKendrick et al., 2003). Granted to this, networking with partners that are ceased to be pivotal in the industry development might lead to less effective patenting. Such partners without cutting edge industrial knowledge might not be aware of raising technologies, emerging technical areas, and consequently lack expertise for valuable patent creation, as well. In addition, technology alliancing with them reduces the potential for knowledge acquisition that optimally could lead to patent creation.

Moreover, also when a firm is not able to update rapidly its patent options, then it can not be so effective in selecting alliance partners. Indeed, non-updated patents could have a scarce role in protecting against knowledge and technology dissipation and could provide less bargaining power to firms.

As a result of noisy signals derived through the non-updated technological options, experiental learning can produce superstitious learning (Levitt & March, 1988; March, 1988; Sorenson, 2000) and can detrimentally effect intra-industry diversification. All these issues point toward the possibility that even a valuable portfolio of intangible assets can have its Achilles' heel under extremely high levels of uncertainty of the environment. If firms are not able to maintain updated the options of their portfolio becuase of the costs generated by raising uncertainty and because of resource constraints problems, they will obtain limited strategic value through their portfolio of R&D option.

Hypothesis 4: In a high-tech, Schumpeterian industry, the benefit of a technological option portfolio to intra-industry diversification is negatively moderated by the level of uncertainty of the environment.

4. Data and methodology

The sample and dependent variable

The Security Software Industry is an appropriate test bed to analyze our hypotheses about the real option framework. This industry is a recent segment of the software industry, a quintessential example of Schumpeterian environments (Giarratana 2004) since it is a turbulent, competitive industry with high levels of uncertainty, firm mortality and product substitution, neglectable economies of scale, compressed product life-cycles (Covin & Slevin, 1989; Nelson & Winter, 1978; Schmalensee, 2000).

A population sample of security software manufacturers was compiled for the analytical purposes. Firms enter the sample when they release the first product in the SSI. Product introduction data were taken from Gale Group’s Infotract Promt (www. gale.com). This data source is the more recent version of the former Predicast database and was applied in various studies (e.g. Pennings & Harianto, 1992). From a large set of trade journals, magazines and other specialized press, Promt reports several categories of events classified by industrial sectors. We searched for all press articles that reported a “Product announcement”, a “New software release” and a “Software evaluation” in SSI (SIC Code 73726) from 1989 to 2003. Then, from each article, we extracted the name of the company, the event date and the six digit SIC code of the product which allowed us to detect the new product release and the exact niche where the firm locates and, should the occasion arise, expands to. From 1989 which was the year of the first product introduced in SSI, to 2003, we registered 921 different entrants that have introduced more than 3,000 different products. According to their SIC code classification, these products were classified in six different niches: Authentication-Digital Signature, Antivirus, Data and Hardware Protection, Firewalls, Utility Software and Network Security and Management (Giarratana & Fosfuri, 2007). Every attempt was made to ensure that the data collection was comprehensive in its coverage of the sampled firms’ product introduction and correct for which we also cleaned for eventual product double-counting.

The dependent variable for this study is the propensity of a firm to enter into a new market niche different from its entry niche. The variable is operationalized as the instantaneous probability or hazard rate of releasing a product in the second market niche that is new to the firm (i.e., it still has no product launched in the niche in question). The entry into the second niche is of key strategic importance because it represents the first attempt of diversification without experience. Therefore, compared to entry into subsequent niches where diversification experience could play a role, the second niche put under scrutiny the sources of benefits provided by real option investment.

Therefore, the unit of analysis is firm entry into the second product niche and the level of the analysis is the firm. We obtained data on the structure of firm groups (including subsidiaries) from the Infotrac Company Resource Data Center, Infotrac PROMT and Hoover's. This latter collects data for the Security Software and Services industry and offers useful information on firm profiles and histories. Since the first product in SSI was introduced in 1989 and our data covers the period from the founding year of the industry until 2003, we are able to avoid the problem of left censoring and completely track the desired intra-industry diversification events.

Independent variables

Strategic technology alliances$_{it-1}$. This time variant variable (lagged by one year) is defined as the total number of strategic technology alliances formed by the firm in the prior years, until it entered into a new market niche. This specification captures the cumulative nature of learning indicated in hypothesis 1. Using the same PROMT database, we downloaded all the articles that reported strategic alliances and joint ventures. These events occurred during the period of 1989-2003 and are classified under the SIC code 73726 (Encryption Software Sector). From these press articles reporting strategic alliances and joint ventures, we selected those ones for the variable strategic technology alliances where partners are involved in combined innovative activities or exchange of technologies. An example is the partnership formed in 2001 between the content infrastructure software provider Interwoven Inc. and Netegrity Inc., a supplier of systems for securely managing e-business. The two US companies worked together to integrate Interwoven's TeamSite software with Netegrity's SiteMinder platform. The joint system was designed to enable companies to streamline content collaboration and content management processes for portals and marketplaces, to allow customers, suppliers and trading partners to securely and efficiently contribute external web content (Telecomworldwire, May 23, 2001). Another illustration for a technological cooperation in the Security Software Industry is the alliance between EnCommerce and iXL. The companies joined to develop a secure internet relationship management platform that enables personalized customer interactions for both business-to-customer and business-to-business commerce. Encommerce's core competence lies in the provision of secure enterprise portal management and its principal product, getAccess software delivers the portal infrastructure of authentication, authorization and administrative services for e-business applications. IXL brings into the partnership its internet strategy consulting expertise that the firm provides to corporate users of information technology (Washington Business Journal, Oct 29, 1999).

Patents$_{it-1}$. Firms' technological competence and capabilities can be effectively grasped by patents (Henderson & Cockburn, 1994; Narin et al., 1987). As Giarratana (2004) explains the sound and sophisticated mathematical core is important competitive advantage in SSI. Not only it signals product quality, but it also makes possible patent protection which can effectively hinder possible imitation (Giarratana, 2004). This variable is measured as the cumulative number of patents filed at the US Patent Office (www.uspto.gov) until the year, the firm entered into a new market niche, and is lagged by one year. The cumulative specification accords well with the growing range of downstream uses we mentioned for hypothesis 2. The patents of security software firms were granted in the USPTO classes 380 ("Cryptography") and 705 which are the fundamental technological classes in the SSI (Giarratana 2004). The use of US Patent Database for all firms, including firms that are headquartered outside the United States is necessary to maintain consistency, reliability, and comparability, as patenting systems across countries differ in their application of standards, systems of granting patents, and value of protection granted (Basberg, 1987).

To exemplify mathematical and software engineering capabilities embedded into SSI patents granted in the strategic USPTO 380 field, we consider the US Patent 6,028,939 filed in 3rd January 1997, by RedCreek Communications Inc. The patent affords flexible and adaptable high performance data security systems and methods which provide cost effective and scaleable solutions to a wide range of data security problems. Cryptographic systems and methods in accordance with this invention have substantially lower cost for equivalent performance (comprising the number of iterations) and substantially enhance flexibility over known systems and methods. Moreover, RedCreek's patented invention enables other processes and functionality, such as data compression, to be conveniently incorporated with data security technology in a highly flexible and advantageous manner.

Option portfolio$_{it-1}$. The interaction of strategic technology alliances and patents is measured by a dummy variable. The Option portfolio variable is defined 1 for a given year if the cumulative value of both strategic technology alliances and patents is greater than zero. The use of a dummy variable compared to a classical multiplicative variable provides a more severe test, because it lowers problems of multicollinearity and "inflated" bias of the results. This latter is also an important issue to take into consideration because firms own both assets simultaneously in only 10% of total firm-year observations. We have entered its one-year lagged value into our regressions.

*Option portfolio*Uncertainty*$_{it-1}$. This is an interaction variable of the option portfolio variable and uncertainty, and is defined for each year by the multiplication of these two variables. We measured uncertainty with the conditional variance generated from autoregressive conditional heteroskedasticity (GARCH) models (Bollerslev, 1986; Price,

1995) on a time series of stock returns in the SIC 7372 industry. This procedure provides a time varying estimate of the conditional variance in such a way that controls for any trends that might exist for each period in the time series (Folta & O'Brian, 2004; O'Brian, Folta & Johnson, 2003). Similarly to O'Brien and Folta (2007), we chose to model stock returns because "they incorporate expected future profitability, and hence, all sources of uncertainty that may impact profitability" (O'Brien & Folta, 2007: p. 21). We ran GARCH models on monthly stock returns of firms listed in COMPUSTAT database from 1986-2003. Our proxy for annual market-level *uncertainty* is the median of monthly stock volatility for all firms participating in SIC 7372.

Controls

We also included a number of time-variant and time-invariant control variables that may be alternate explanations for observed niche entry behavior. First of all, to measure competitive forces, we introduce the number of firms operating in the SSI, for each year, using the one-year lagged value (*density*). The variable *age in market* is included as a control for the possible effect of market experience. We simply counted the number of years, a given firm spent in the SSI. Since our sample is mostly composed by small-to-medium sized, young firms, traditional time-varying measures of firm size (e.g. sales, number of employees) are difficult to obtain. Following Giarratana and Fosfuri (2007), we proxied size by the stock of *trademarks* that the firm had registered at the US Patent and Trademark Office for every year of its market presence in the SSI. Based on interviews with managers of SSI firms, Giarratana and Fosfuri (2007) conclude that "trademarks are a fairly good indicator of a firm's volume of activity". Moreover, Seethamraju (2003) detected high correlation between a firm's sales and its stock of trademarks. To control for the effect of industry fluctuations, we used the Compustat database to include annual financial data for the Software industry, such as the earnings before interest and taxes (e*bit*) variable. We control for the *systematic risk* of the industry relative to a wider set of industries (Folta & O'Brian, 2004; O'Brian et al., 2003). This variable is calculated as the covariance over the previous 5 years between the returns of all listed firms competing in SIC 7372 and SIC 73 (data were taken from Compustat). As a continuation, the introduction of the *uncertainty* variable would follow. Due to earlier detailed discussion about the computation of the *uncertainty* variable, we only would like to note here that the incorporation of this variable into our models is a necessary condition to draw conclusions in the spirit of real options theory (in contrast to industrial organization or resource based perspectives). In addition, strategic decisions on entry in a new market niche will cause automatically uncertainty, implying an unavoidable necessity toward its (correct) measurement.

The time-invariant control variable, age at entry (*entry age*) seizes pre-entry conditions. We calculated it as the difference between the year of entry and the year of a firm's foundation. Past literature studied the magnitude and sustainability of first-mover advantages (Lieberman & Montgomery, 1988). To capture for possible early entry advantage in the Security Software Industry, a dummy variable, called "*pioneers*", was created that takes the value 1 if a firm entered in the period 1989-91, the first 3 years, and 0 otherwise. Early entrants might benefit from 'first-mover' advantages through economies of learning, established reputation and the existence of switching costs that is common in the entire software industry (Torrisi, 1998). Finally, we inserted a dummy variable (*US firm*) that takes the value 1 if the organization is a US firm, and 0 otherwise. This variable is supposed to correct the possible distortion effect for non-US firms in the USPTO data source.

Model estimation

We use event history analysis to model firm diversification behavior for our organizational population. Hazard rate models are used as they incorporate information from 'right-censored' cases. Treating these cases as if they never again entered into intra-industry expansion could severely bias coefficient estimates (Sorenson 2000). If T is the duration since the firm entered the SSI, then the hazard rate of entering into a new market niche at time t is defined as

$$\lambda(t) = \underbrace{\lim}_{\Delta t \to 0} \frac{pr(t \le T < t + \Delta t \,|\, firm \cdot competes \cdot in \cdot the \cdot industry \cdot at \cdot t)}{\Delta t},$$

where pr(.) is the probability of entry into a new market niche in the period running from t to t + Δt, conditional on competing in the niche of entry at time t. We modeled the hazard rate using piece-wise constant exponential specification which is a flexible means for representing temporal variation in transition rates. This model essentially breaks the relevant temporal dimension into pieces and assumes that the hazard is constant not over the whole range of time, but within certain specified intervals of time. Within each of these pieces, the base rate for diversification remains constant, but the effects vary freely across pieces. The equation under estimation takes the following specification:

$$\lambda(t) = \exp(\alpha_t + X\beta),$$

where X is a matrix of control and independent variables, β is a vector of unknown regression parameters which are assumed not to vary across time, and α is a constant coefficient associated with the t time period (Blossfeld & Rohwer, 2002).

5. Results and discussion

Table 1 and 2 present descriptive statistics and a partial correlation matrix for the variables covered in the analysis. The partial correlations exhibit significant values for the majority of the cases.

Insert Tables 1 and 2 about here

Table 3 presents the results of the exponential piecewise-constant hazard rate models of the likelihood of firm entry into a new market niche, conditional on the entry into the Security Software Industry. The first column reports the baseline log pseudo-likelihood of such an event with the control variables. To test for the independent effects of each of the variables of theoretical interest, we include progressively all the core variables measuring their separate effects in Models 1 through 4 in Table 3. The increase in log pseudo-likelihood is statistically significant as compared to the baseline model. Variable addition increases the model's fit, as implied by the chi-square test of significance (χ^2 = 22.33 for Model 1 vs the baseline; χ^2 = 3.94 for Model 2 vs the baseline; χ^2 = 143.68 for Model 3 vs the baseline; χ^2 = 159.54 for Model 4 vs the baseline). Through Model 1, Hypothesis 1 gains support from the data since the parameter estimate of the variable strategic technology alliances is positive, statistically significant, and in the hypothesized direction. If all other variables are held at their mean values, a firm realizing, for example, eight strategic technology alliances is 38.6% more likely to enter a new niche within the same industry than a firm with forming only one strategic technology alliance (exp[0.0466*(8-1)], using estimates from Model 1). Model 2 tests the effect of the cumulative number of patents. The parameter estimate of this variable is positive and statistically significant, offering strong support for Hypothesis 2. Model 3 demonstrates the positive and significant effect of the option portfolio variable which corresponds with Hypothesis 3. Additionally, Model 4 tests Hypothesis 4 regarding the contingent nature of the advantages of holding a portfolio of technological options. The multiplicative term between option portfolio and uncertainty is negative and significant corroborating the hypothesis. This result is consistent with O'Brien et al. (2003). Their study shows that uncertainty negatively moderates a firm's intangible assets to entry (O'Brien et al., 2003). Model 5 is the full model and a complete specification including all variables. All the independent effects continue to be significant in this model, reaffirming earlier results, thus furthering Hypotheses 1-4.

Insert Table 3 about here

As far as our control variables are concerned, industry *density* shows a negative and significant effect on diversification. This underlines the role of competitive forces in shaping change in market structure of a Schumpeterian environment. As more and more firms populate the industry, discourages incumbents from doing intra-industry maneuvers. Instead, they would adopt a versioning strategy (Giarratana & Fosfuri, 2007). The population exhibits negative age dependence, evidence of quickly making the best of arising market opportunities, which is a crucial aspect in a high-tech Schumpeterian industry. Surprisingly, size appears to have little effect on intra-industry diversification in SSI. Although the variable *trademarks* positively impacts entry rates in the baseline model, this effect fails to meet significance levels when our measures of technological investments enter Models 2-5. This underpins the less importance of firm size to realize growth strategies in an environment where the new and smaller venture is the dominant organizational form. Perhaps, combined features of the software industry and technology driven Schumpeterian environments, such as scarce scale economies, innovativeness and importance of product reputation (Giarratana, 2004; Torrisi, 1998) outweigh size benefits. It shows similarity with Giarratana and Fosfuri' result (2007). Using the same test bed they concluded that firm size did not exert a significant effect on exit from the industry.

The negative and significant effect of the industry measure *ebit* on intra-industry diversification, in all models, is an interesting finding, per se. Perhaps, ceteris paribus, when things are going well in the business environment, company managers might feel fewer incentives to involve their organization into expansion strategies. Indeed, the average annual growth rate in the study period enjoyed a 13 percent increase in the Software industry (US Census Bureau's Service Annual Survey 1998, 2002 and 2004). The *systematic risk* of the industry relative to a wider set of industries is not a decisive factor for within-industry strategy. However, *uncertainty* within the industry exerts a significant negative effect on new entry niche strategies. This finding does not conflict with prior research that finds that environmental uncertainty attenuates entry (Campa, 1993; Folta & O'Brian, 2004; O'Brien et al., 2003).

The *entry age* variable displays a significant effect in none of the models which suggest de alio firms do not enjoy any benefits compared to de novo organizations. The dummy variable for early entrants into the industry (*pioneers*) is significant in all models. It underscores the possibility of first-mover advantages toward expansion for firms that have entered the SSI during the formative years of the industry. This finding buttresses former evidences that early entrants benefit in the long run from their first-mover position through product reputation, lead time and network effects, access to existing customers and (psychological) switching costs (Gandal, 2001; Makadok, 1998). Finally, the *US dummy* variable fails to deliver any significant effect on intra-industry diversification in any of our models.

6. Conclusions

In summary, this study highlights the link between organizational investments in real options (ROR) and firms' intra-industry diversification strategy. Our theoretical approach suggests that in Schumpeterian environments decision-makers do either intuitively or explicitly use ROR when making R&D investments under uncertainty. Using data from the Security Software Industry, our results show that the firm stock of strategic technology alliances and patents affect positively the probability to enter in a new product niche (measured by the entry in the second niche within the same industry). In this respect, we are able to corroborate Bowman and Hurry's assertion that ROR is an appropriate tool for industry positioning (Bowman & Hurry, 1993). To that extent that growth is key to survival and industry positioning, successful innovators grow more compared to other firms. Under highly uncertain Schumpeterian competitive conditions, possibility for strategic positioning, altogether with the fact that at the time of an investment its future benefit is not yet known, elevate ROR as one of the most relevant approach. ROR perspective holds more in a Schumpeterian environment where intense competition spurs firms to monitor a wide range of technologies and introduce more and more technologically complex goods in the market. This variety might also help to unlearn unnecessary and obsolete skills, offset organizational inertia and enrich firms' cognitive search. Firm ability of granting patents in technological classes strategic for an industry resembles much to the possession of key component knowledge unique to the industrial system (Henderson & Clark, 1990), because it demonstrates a firm-level understanding of the scientific knowledge underlying the entire system. Insofar as the firm requires a brand new, technologically sophisticated product for new niche entry, we underpin Kotabe and Swan (1995) by concluding that technological alliances greatly help to set high the level of product innovativeness of firms.

One of the most interesting results is concerning the option portfolio. If firms are to activate more than one sort of option simultaneously, they clearly enjoy more chance for new niche entry. Producing a good or service typically requires the application of many types of knowledge (Kogut & Zander, 1992). To this end, for firms it is highly beneficial to build and piece out their knowledge base via the joint application of internal and external options, such as patent development, and strategic technology alliances. However, we have also found that the positive value of the firm option portfolio in explaining intra-industry diversification is negatively moderated by the level of uncertainty.

As secondary findings, we show that entry age of firms and size play a marginal role for intra-industry diversification, while early entrants benefit from their first-mover position. In conjunction with the important role of technological investments, we relate these stylized facts to the particular attributes of the SSI, where product reputation, lead time effects, access to existing costumers and innovativeness are key factors for market success (Gandal, 2001; Giarratana, 2004; Giarratana & Fosfuri, 2007; Makadok, 1998; Torrisi, 1998). Furthermore, our focus on intra-industry diversification using a longitudinal, large sample mitigates the paucity of studies conducted in the field (Li & Greenwood, 2004; Siggelkow, 2003). Our analysis provides value addition for the research of this phenomenon as investigates it in a high-tech, early stage industry where within-industry entry into a new niche is of prime importance for firm growth (Giarratana & Fosfuri, 2007).

Technological investments through real options could have a significant managerial relevance. Our results show that firms effectively committing ROR strategies obtain higher chances in terms of market opportunities. The message is clear for managers and practitioners: if they apply the ROR logic, then their organizations will become more aware of the significance of market opportunities present in the environment, and will grasp those opportunities in a more proactive matter. Thus, a ROR-based firm strategy is a viable one in turbulent industries and could contribute greatly to the creation of competitive advantage.

Future research could improve and build on this paper by providing an in-depth analysis about how uncertainty affects the focus of R&D investments within the firm. Perhaps, a case study would be an appropriate tool to demonstrate any shift that may occur in the management of R&D work when managers perceive significant increase of uncertainty in the business environment. Relatedly, interviews with CEOs and senior managers could illuminate the role and the mechanisms of fast strategic decision making (Eisenhardt, 1989) concerning the execution of different R&D activities which ultimately influences the product-market performance of the firm. Another line of research could also discover the exact components of environmental factors that might underline such a reconfiguration strategy of R&D work. Further, if the detection of such environmental factors is feasible, their separate cost effects could be teased out which might explain any change in firms' innovative behavior and in the concomitant R&D real options strategy.

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Table 1

Simple statistics of variables

Variable		Mean	S.D.	Min	Max
Time-variant controls					
1	Density	131.43	105.50	0	317
2	Age in market	2.36	2.49	0	11
3	Trademarks	22.68	114.42	0	2369
4	EBIT of software industry	5324.23	9505.49	-12300	18000
5	Systematic risk	7.08	11.06	-1.38	31.69
6	Uncertainty	2.86	1.53	0.68	5.06
Time-invariant controls					
7	Entry age	6.41	13.90	0	159
8	Pioneers	0.07	0.25	0	1
9	US dummy	0.74	0.44	0	1
Core variables					
10	Strategic technology alliances	0.37	2.15	0	62
11	Patents	1.79	15.46	0	642
12	Option portfolio	0.09	0.28	0	1
13	Option portfolio*Uncertainty	0.27	0.99	0	5.06

Table 2

Bivariate correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.00											
2	0.07	1.00										
3	-0.02	-0.01	1.00									
4	-0.57	0.16	-0.01	1.00								
5	0.19	0.20	-0.03	0.45	1.00							
6	0.63	-0.04	0.00	-0.73	0.01	1.00						
7	0.04	-0.11	0.49	-0.02	0.04	0.07	1.00					
8	-0.21	0.27	-0.03	-0.02	-0.16	-0.23	-0.07	1.00				
9	-0.04	0.04	-0.03	-0.01	-0.03	-0.03	-0.05	0.12	1.00			
10	-0.02	-0.02	0.26	-0.02	-0.04	0.03	0.08	-0.05	0.02	1.00		
11	0.02	-0.04	0.53	-0.05	-0.02	0.05	0.25	-0.03	-0.03	0.21	1.00	
12	-0.03	-0.04	0.31	-0.05	-0.07	0.05	0.13	-0.08	0.06	0.47	0.26	1.00
13	0.06	-0.04	0.28	-0.15	-0.05	0.19	0.14	-0.07	0.04	0.41	0.28	0.88

Correlations with an absolute value of 0.03 or more are significant at $p < 0.05$.

Table 3

Piecewise-constant exponential regression models of likelihood of entering into a new market niche for SSI firms, 1989-2003

Independent variables	Baseline	Model 1	Model 2	Model 3	Model 4	Model 5
Time-variant controls						
Density	-0.0739**	-0.0732**	-0.0738**	-0.0739**	-0.0787**	-0.0779**
	(0.0054)	(0.0054)	(0.0053)	(0.0063)	(0.0092)	(0.0088)
Age in market	-0.1557**	-0.1583**	-0.1504**	-0.1620**	-0.1640**	-0.1620**
	(0.0247)	(0.0248)	(0.0246)	(0.0251)	(0.0253)	(0.0253)
Trademarks	0.0012**	0.0008**	0.0008*	0.0002	0.0002	0.0000
	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
EBIT of software industry	-0.0013**	-0.0012**	-0.0013**	-0.0012**	-0.0013**	-0.0013**
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Systematic risk	0.2421	0.2552	0.2368	0.2767	0.3266	0.3311
	(0.2365)	(0.2271)	(0.2378)	(0.2171)	(0.2252)	(0.2202)
Uncertainty	-6.1570**	-6.1075**	-6.1424**	-6.1292**	-6.1665**	-6.1117**
	(0.5135)	(0.5109)	(0.5118)	(0.5229)	(0.6094)	(0.5955)
Time-invariant controls						
Entry age	0.0018	0.0033	0.0027	0.0006	0.0013	0.0018
	(0.0032)	(0.0028)	(0.0031)	(0.0025)	(0.0023)	(0.0022)
Pioneers	0.6831†	0.7356†	0.6582†	0.9994*	1.1181**	1.1075**
	(0.3862)	(0.3869)	(0.3860)	(0.3942)	(0.4057)	(0.4056)
US Dummy	0.2932*	0.2474*	0.2899*	0.1197	0.0993	0.0993
	(0.1198)	(0.1178)	(0.1199)	(0.1152)	(0.1140)	(0.1140)
Core variables						
Strategic technology alliances		0.0466**				0.0170*
		(0.0124)				(0.0086)
Patents			0.0030**			0.0015**
			(0.0007)			(0.0005)
Option portfolio				1.6397**	2.9859**	2.9501**
				(0.1026)	(0.3397)	(0.3408)
Option portfolio*Uncertainty					-0.3516**	-0.3616**
					(0.0811)	(0.0816)
LogPseudoL	1568.26	1579.43	1570.23	1640.10	1648.03	1649.59
d.f.	24	25	25	25	26	28
N	921	921	921	921	921	921

350 niche entrances, 3583 organization-years. † indicates $p < 0.1$, * indicates $p < 0.05$, ** indicates $p < 0.01$.
Values in parentheses are heteroskedastic consistent standard errors.

THIRD PAPER

LOCATION CHOICES OF EXTERNAL TECHNOLOGY SEARCH: THE ROLE OF UPSTREAM AND DOWNSTREAM IPR ASSETS

ABSTRACT

Previous literature postulates the importance of external technology search (ETS) for firms' competitiveness, especially in case of technology intensive industries. We combine insights from innovation management, external technology search and the geographic component of firm strategy to examine the effect of intellectual property rights (IPR) on firms' isolation strategy of ETS. This study distinguishes two types of ETS: acquisitions and strategic technology alliances. We argue whether firms are able to realize less intensity of geographic overlap in ETS locations compared to competitors, is a function of upstream (patents) and downstream (trademarks) IPR tools that can also vary along a generality (at patents) and a diversification (at trademarks) dimension. When distinguishing firm competences by patent stock, generality of patent stock, stock of live trademarks, and diversity of live trademark stock, we obtain that all IPR-related covariates influence the spatial isolation of ETS to a greater or smaller extent. Consequently, the paper reveals some subtleties concerning the effects of diverse IPR assets on the isolation of different forms of external technology search vis-à-vis industry rivals. In addition, we find that more industry experience and harsher competitive conditions at entry compel firms to augment the geographical divergence for targets of acquisitions, and that similarity in technological background and in place of origin can also influence location decisions for ETS. We test our hypotheses using a novel data set on firms' global ETS location decisions from the technology intensive Security Software Industry by considering firm dyad as the unit of analysis.

KEYWORDS: external technology search, intellectual property rights-related upstream and downstream assets, location index of external technology search, security software

LOCATION CHOICES OF EXTERNAL TECHNOLOGY SEARCH: THE ROLE OF UPSTREAM AND DOWNSTREAM IPR ASSETS

1. Introduction

Air Products and Chemicals seeks ideas outside of its organizational boundaries as a central aspect of its business strategy (Rigby and Zook, 2002). The geographically widespread search for external R&D labor provides access for untapped expertise and extends greatly its capacity for innovation. In addition, these external technology links “save the company hundreds of thousands of dollars in net research costs” while generating abundant profit. External technology search has primary importance at Procter & Gamble, too (Sakkab, 2002). The firm pursues a “connect and develop” strategy to enrich its innovation portfolio with tools that embrace joint technology development, licensing of intellectual property, and tapping government and university sources, among others.

Correspondingly, the knowledge and technology search branch of strategic management literature does highlight the imperative role of knowledge and technology seeking for firms (Kim and Kogut, 1996; Rosenkopf and Nerkar, 2001). Such organizational behavior that aims to source externally generated knowledge is more pronounced if the focal industry undergoes a rapid technological change (Chung and Alcácer, 2002), and if technology development exhibits a clear pattern for complexity due to technological interdependencies (Dodgson, 1989). Prior research indicates a strong correspondence between external technology search (ETS) and geography owing to the significant variation in innovative activity that can take place across regions within the same country (Almeida and Kogut, 1999; Saxenian, 1994), and to the specific factors that can be tapped at distinct locations (Cantwell, 1989). Such crucial external factors can be even accessed from resource-poor firms if those are located in resource-rich areas that promote them to invest in technology innovation (Forman, Goldfarb and Greenstein, 2008).

At the same time, however, there exists another argument that can trigger a geographically isolated realization of ETS from rival entities. As knowledge spillovers can be captured from geographically proximate competitors (Jaffe, Trajtenberg and Henderson, 1993), a defensive argument concentrates on firms' interest in protecting their own technological knowledge from rivals by a means of locating apart and avoiding geographic clustering (Shaver and Flyer, 2000). As a matter of fact, studies recognize that firms can perceive the balance of knowledge in- and outflows (Cassiman and Veugelers, 2002), and corresponding to possible knowledge spillover benefits, they can actively shape location strategies to preserve or augment their technical capabilities vis-à-vis rivals in the industry (Alcácer and Chung, 2007).

In his article, Alcácer (2006) investigated a possible link that might exist between the ability level of firms and the geographic component of their strategies. He pointed out that the actual location behavior of R&D, production and sales subsidiaries is a function of firms' organizational strength, which permits more-capable firms to collocate less (and isolate more) than less-capable firms. In this paper we concentrate on the organizational strength dimension and attempt to examine its role on organizations' geographic location decisions of external technology search (ETS). We explore this issue through distinguishing firms' relative strength in intellectual property right (IPR) at upstream and downstream levels. A vertical distinction has its *raison d`étre* as the level of these organizational competences can significantly vary between upstream and downstream levels (Arora, Fosfuri and Gambardella, 2001; Gans and Stern, 2003; Teece, 1986).

In this context we formulate the following four research hypotheses: (a) firms with larger stock of patents are more likely to have less intensity of geographic overlap in external technology search locations compared to rivals; (b) firms with more general stock of patents are more likely to have less intensity of geographic overlap in external technology search locations compared to rivals; (c) firms with larger stock of trademarks are more likely to have less intensity of geographic overlap in external technology search locations compared to rivals; (d) firms with more diversified stock of trademarks are more likely to have less intensity of geographic overlap in external technology search locations compared to rivals.

We empirically test these propositions on a unique dataset that is built upon the worldwide Security Software Industry (SSI). The practice of external technology search in SSI is a widespread activity because (i) it is a technology-based industry with enhanced product innovation, (ii) competition is fierce implied by low entry barriers and a high hazard rate of firm exit, (iii) new lucrative product categories proliferate, and (iv) the design of a security software system is a complex undertaking.(Giarratana, 2004; Giarratana and Fosfuri, 2007).

We examine two distinct mechanisms of ETS, such as acquisitions and strategic technology alliances to which we assemble a comprehensive panel dataset of four years between 1999 and 2002. As the hypothesized relationships are inherently dyadic, we built up our sample of dyadic pairs of firms for which we incorporated 119 security software firms that performed at least one ETS in the study period. We use the quadratic assignment procedure that permits us to analyze the sampled firms' geographic dispersion of ETS in a dyadic fashion.

Our empirical results suggest that all core covariates – patent stock, patent generality, trademark stock and trademark diversification - support a geographic isolation of external technology search. However, they play different roles depending on the type of the search activity, and partly on the level of geographic gradation applied. Our results suggest that firms with large preexisting stock of industry-core patents decrease the intensity of geographic overlap only in acquisitions vis-à-vis industry competitors. This pattern holds the same for all geographic areas. A more general preexisting stock of industry specific patents augments the geographic isolation at both strategic technology alliances and acquisitions. Interestingly, its effect is slightly stronger in case of placing the level of investigation to the regions. The stock of a firm's live trademarks is also an important IPR-related covariate as it lowers the extent of geographic overlap compared to rivals for both types of ETS. An exception emerges only because its effect for acquisitions at cluster level is insignificant. The last important covariate, the diversification of an organization's live trademark portfolio causes less intensity of spatial overlap compared to rivals exclusively at acquisitions, and mainly at regional level because its effect at cluster and country level is significant only on the margin. In sum, a spatially divergent portfolio of acquisitions vis-à-vis rivals is supported by all external tools in a bigger or a smaller extent. Additionally, the stock of live trademarks and the generality of patents are primarily responsible for the geographic isolation of strategic technology alliances.

This work links together several branches in the literature, such as innovation, external technology search and the geographic component of firm strategy. We are able to demonstrate the strategic value of location choices where firm upstream and downstream intellectual property rights play an indispensable role. An important contribution of the study is that it jointly incorporates technology alliances and acquisitions as key external knowledge and technology channels for organizations. By constructing a panel dataset, we are able to assess in a dynamic style that the location patterns of external technology search are a direct consequence of firm IPR-related assets. In addition, we can enhance our understanding on firms' location patterns of ETS via applying a diverse geographical classification. Finally, we follow prior research that considers trademarks as important assets for firm strategy (e.g. Fosfuri, Giarratana and Luzzi, 2008; Fosfuri and Giarratana, 2009). This paper offers a value addition in terms of measurement as it directly captures the diversification dimension of this downstream IPR asset.

2. Theoretical background

The ability to compete in high-technology industries depends on the acquisition of competitive knowledge, implying, that a firm has to attain experience with the underlying science and related technological fields (Kim and Kogut, 1996). Some of these newly acquired capabilities serve the firm to respond rapidly to market changes and allow for expansion during windows of opportunity (Kim and Kogut, 1996). Studying patenting activity in optical disc technology, Rosenkopf and Nerkar (2001) show that exploration spanning organizational boundaries consistently generates higher impact on subsequent technological evolution, thereby it can provide for the explorer organization a competitive advantage within the industry, and an option to diversify. Resorting to external exploration is desirable as technological evolution is generated by communities of organizations (Rosenkopf and Tushman, 1998). For instance, the evolution of products with the underlying components can be viewed as the result of variation, selection and retention processes that take place by a broad community of organizational actors (Rosenkopf and Nerkar, 1999). This feature influences a firm's technological trajectory and make all industrial actors mutually interdependent.

To maintain or enhance competitive edge, firms might be motivated to employ ETS for search of new capabilities, and presumably to recombine those newly acquired or accessed capabilities with existing skills. This motive has been termed technology or knowledge seeking, and such organizational search behavior may be more prevalent if a firm competes in a technology intensive industry (Chung and Alcácer, 2002). We expect some firms to value locations' traits that reflect the level of localized technical activity. The uniqueness of a location relies much on location-specific factors that can nurture technologies not available elsewhere (Cantwell, 1989). Even a relatively resource-poor firm but being situated in a bigger resource abundant location can considerable improve chances to realize investment in innovative processes (Forman, Goldfarb and Greenstein, 2008). Tapping localized technology source is greatly enhanced by frequent inter-partner interaction as relevant knowledge can be tacit and the prerequisite of its transfer depends on physical propinquity (Kogut and Zander, 1992). This idea that firms seeking new knowledge have to approach the target locations is reaffirmed by Almeida and Kogut (1999). They demonstrate that localized knowledge builds upon cumulative ideas within regional boundaries, and as knowledge is frequently tacit that knowledge resides with engineers of a particular geographic community. Cantwell and Odine (1999) bring evidence that firms emanating from leading technical centers are also likely to pursue technological strategies in which they geographically differentiate their innovative activities abroad. In contrast to firms from more laggards technical centers whose primary interest relies in catch-up, they are primarily focused on sourcing more diverse technical knowledge. Studying inward FDI into the United States, Chung and Alcácer (2002) make a parallel inference, arguing that knowledge seeking takes place not only among technical laggards, but is also ubiquitous among technically leading firms.

Acknowledging the potential for higher added value and nonredundant knowledge to be captured from geographically distant organizations, a defensive argument puts emphasis on geographically isolating external technology search vis-à-vis competitors. Certain industries are based upon technical competition, which may force all participants to seek spillovers from competitors. The study by Shaver and Flyer (2000) argues that firms with the best technologies have strong motivation to geographically distance themselves, otherwise their technologies with other key resources spill over to competitors which become stronger and eventually endanger the competitive position of the former. Chung and Alcácer (2002) arrive to a similar conclusion in connection with foreign technically leader, flagship firms as those ones opt to spatially isolate themselves from existing clusters in the United States to prevent outward knowledge spillovers to rivals. Such unwanted outgoing knowledge spillover can occur as the level of knowledge in- and outflows is not exogenous to the firm, but the recipient firm can affect the extent of incoming spillovers through a deliberate innovation strategy (Cassiman and Veugelers, 2002). In a related paper, Alcácer and Chung (2007) recognize that firms are active entities in making decisions upon location strategies in terms of net spillover benefits they may get, and thus are aware of the possible cost of outward spillovers. A link between organizational strength of firms and location choice appears in Alcácer's paper (2006), in which he finds that technologically more advanced firms favor to collocate less their R&D, production and sales subsidiaries as opposed to less capable firms.

As it becomes clear from the above discussion, an organizational strategy to flock with or flee from within-industry competitors in ETS relates closely to firm resources. Our attempt is to show that downstream and upstream organizational resources in intellectual property right can potentially act as driving forces for firms to geographically isolate their external technology search networks. As a matter of fact, we examine patents and trademarks, the two types of IPR tools along the verticality from upstream to downstream. In deriving our hypotheses, we also take into consideration the generality and diversification dimension of patents and trademarks, respectively.

3. Hypotheses

Upstream competences: patents

A larger, industry-core patent portfolio provides greater resilience and latitude in ETS that lowers the extent of geographic overlap *vis-à-vis* competitors through three main mechanisms.

The first reason touches upon some intellectual property right-related benefits. Patents provide a tight appropriability regime (Teece, 1986) that affords the innovator firm with sufficient time to perform and take advantage on a throrough search for external technology links in the techno-geographic space. Such a lead-time advantage comes from the impenetrable thicket of patents that renders a technology simply difficult to copy legally. On the one hand, this lead-time advantage may provide time to spatially expand the selection of the applicable and the best external available technologies to be recombined. An important aspect to be considered, as firms often tend to outsource technologies instead of in-house elaboration (Cesaroni, 2004). On the other hand, it leaves time to perform a joint undertaking with external partners.

The second reason is strategic. A firm with a portfolio of large stock of industry specific patents is more effective at applying competitive pressures to rivals in forming ETS links. Particularly, greater stock of patents look more attractive for generating knowledge flows in the eyes of potential partners, thus the focal firms can easier approach those firms that are located in capability rich areas. By a related consideration, owning a large patent stock can signal a technology leader position in the industry (Garud and Kumaraswamy, 1993) which might offer a possibility for exploiting this reputation of a technology champion, whereby creating a spatially divergent set of technology search locations with respect to less capable rivals. Therefore, less-capable competitors will prove to be less attractive candidates that reduce their opportunities to break in geographically divergent set of locations. An additional source of advantage is that, a large industry-core patent portfolio facilitates broader partner selection with complementary patens and technologies.

The third mechanism is defensive and also indicates a lower extent of geographic overlap in technology search network. Patents represent strong IPR protection that reduces the cost of leakage of relevant knowledge to partners. By a large portfolio of patents, the owner can enjoy stronger bargaining position in a technology cooperation which increases productivity (Makhija and Ganesh, 1997). Similarly, because of legal control through patents (Arora and Ceccagnoli, 2006), they decrease expropriation and reverse-engineering committed by partners in ETS endeavors. When establishing multiple technological cooperations involves risk for the firm to infringe patents held by other entities. However, a larger patent portfolio of the searcher organization through stronger bargaining power elevates chances to avoid litigation or to establish friendly agreements with potential litigators. Studying the semiconductor sector, Hall and Ziedonis (2001) and Ziedonis (2004) demonstrate that when there is a fragmented market for technologies, large patent portfolios help resolve hold-up problems via the use of cross-licensing agreements.

So taking into account all the positive consequences of a large patent portfolio for the isolation of external technology search, we make the following hypothesis:

> HYPOTHESIS 1. *Firms with larger preexisting stock of patents will have less intensity of geographic overlap in external technology search locations compared to rivals.*

Firms with a more general patent portfolio can enjoy a different sort of benefits whereby they are able to increase the geographic isolation of technology their search channels against competitors. A more general knowledge base creates a higher potential absorptive capacity (Lane and Lubatkin, 1998; Zahra and George, 2002) that extends an organization’s possibility to value and assimilate external knowledge. This component increases the overall level of absorptive capacity that let firms manage external knowledge flows more efficiently, and, consequently, stimulate innovative outcomes (Escribano, Fosfuri and Tribo, 2009). This leads to less information asymmetry in evaluating the quality of the skills of potential partners that operate in a different segment of the industry. Lower expected costs due to higher absorptive capacity gives the firm more freedom for trial and error experimentation. Therefore, a firm incurs less search costs of ETS which permit to augment the spatial divergence of its ETS locations from rivals. Another benefit of greater absorptive capacity is that it can lead to differential learning in knowledge intensive interfirm collaborations (Kumar and Nti, 1998). This positively impacts the knowledge appropriated and the claims to the fruits of collaboration vis-à-vis rivals. Higher levels of absorptive capacity can also prove to be beneficial to spot firms with good technology in the external environment. Relatedly, wider absorptive capacity through more general knowledge background can borrow more awareness on the stance of technology evolution. Like an alarm, it can compel senior managers to update the firm knowledge base in case of necessity.

A more general patent portfolio provides more general skills that can increase knowledge coordination in ETS links. Improved knowledge coordination contributes to the better exploitation of synergies and to the rate of organizational learning (Zollo and Winter, 2002). Also, organizational members might have better abilities to integrate contextually different knowledge in a resilient way across disciplinary boundaries. As a consequence, it makes worthwhile to exploring far locations if such contextually different knowledge is only available elsewhere. Owen-Smith and Powell (2004) show that centrality in a geographically dispersed network positively affects the level of innovation. An implication of this finding could be that if an organization has a more general knowledge base, then it can better occupy a central position in such a network. Furthermore, a more general knowledge base with enhanced learning potential can promote a “connect and develop” strategy that leverages external capabilities in order to enrich the connecting firm's innovation portfolio (Sakkab, 2002).

There is a dominant trend showing that new technologies start to have an increasing tendency for complexity according to contemporary technological interdependencies (Dodgson, 1989). Consequently, products that are based heavily on research and innovation, become complex and start to increasingly rely on more generalized and abstract knowledge – a pattern that has been observed by Arora and Gambardella (1994) in industries like biotechnology, semiconductors and software. The more general technological background a firm has, the better it can face to this challenge in science-driven environments through being effectively equipped for ETS with firms of divergent knowledge background.

Hence:

HYPOTHESIS 2. *Firms with more general preexisting stock of patents will have less intensity of geographic overlap in external technology search locations compared to rivals.*

Downstream competences: trademarks

Our next proposition suggests that firms with large complementary or downstream assets to product commercialization have strong incentives to spread external technology search in the geographic space. Teece (1986) argues that, in almost all cases, the successful commercialization of an innovation requires complementary assets and that the ownership of such assets can position the innovator advantageously. Correspondingly, the lack of those assets can force a technology entrepreneur to sell its technology instead of commercialization (Gans and Stern, 2003; Arora and Ceccagnoli, 2006). For instance, brand advertising can contribute to the creation of stronger downstream assets either by greater brand loyalty due to higher perceived customer differentiation (Lancaster, 1984), or by elevating entry barriers to competitors when the brand acts as a reference in its category (Kapferer, 1997).

An efficient form of creating downstream assets is through registering trademarks that secure legal protection of technological investments by boosting the rate of appropriability (Fosfuri, Giarratana and Luzzi, 2008). A large stock of trademarks key to the scope of operation is a signal of conscious investments into a firm's own brands, reputation for perceived quality, customer loyalty and distribution channels (Mendonça, Santos Pereira and Mira Godinho, 2004). Investment into trademarks provides good protection of marketing efforts as a strong brand along a reputation for quality transforms into an intangible asset that is not easily imitable for competitors. Linking this with the fact that an efficacious way to own markets is to own brands (Aaker, 1991), trademark registration represents valuable efforts to develop and strengthen a business. Trademarks also protect brands against low-priced copycats as the aggrieved party can seek legal remedies for any market advantage enjoyed by the copycat due to confusion, mistake or deception (Warlop, Ratneshwar and van Osselaer, 2005). In consequence of the vantage-point for a successful commercialization, firms with larger number of trademarks can enjoy more freedom in selecting external technology partners.

Past research points out correspondence between a firm's own trademarks and its pecuniary features.. For instance, Fosfuri and Giarratana (2009) find that filed trademarks relevant to the industry in question, imply larger financial firm value. Prior studies also detect that trademarks strongly correlate with company sales (Seethamraju, 2003) and stock market value (Smith and Parr, 2000). Similarly, registered trademarks can promote entry into the market for trademark licensing to obtain pecuniary returns (Mendonça, Santos Pereira and Mira Godinho, 2004). Furthermore, many trademarks within a category that might involve highly-ranked brands and more inferior perceived ones by customers, can imply to pursue a strategy that Shapiro and Varian (1998) label “linking price to value”: a firm can subtract more profit from the same product category when it segments customers along the application of different prices and version the same product along different characteristics. As a consequence one can expect larger stock of trademark piled up in the focal industry to contribute to the financial fit of the firm. Then, in theory, more resources to be allocated can increase the geographic isolation of technology search channels vis-à-vis competitors with less volume of such downstream assets.

We capture this set of arguments to hypothesize:

HYPOTHESIS 3. *Firms with larger preexisting stock of trademarks will have less intensity of geographic overlap in external technology search locations compared to rivals.*

We start with the observation that a more diversified trademark stock generally encompasses brands from a broad range of product categories. To achieve wide product scope, the organization had to undergo a continuous and repeated sequence of changes that identifies the underlying organizational routines of this group of firms (Sorenson et al., 2006). Therefore, they might continue the strategy of growth in future. Such firms might develop the ability to accommodate new technologies due to former expansions, and the acumen to analyse the potential use of a technology due to the experience with a wide range of products. A more dispersed product portfolio might also represent task to the holder organization as a wider product portfolio needs to be updated with more new knowledge elements. This can require numerous novel technologies to embed that, chasing the firm to explore partners with potential technologies, may involve a spatially divergent external search compared to rivals.

Firms having stakes in many product categories through its trademark diversification can enjoy some sorts of positional advantages like increased stability in a more uncertain business environment (Dobrev, Kim and Carroll, 2002), more strategic latitude for managers to hedge their bets (Sorenson, 2000), and increased entry barriers against newcomers (Lancaster, 1990). Furthermore, consumers might find it convenient to buy on the idea of one-stop shopping (Siggelkow, 2003), and, should consumer preference be positively correlated, a product bundling strategy might be implemented (Gandal, Markovich and Riordan, 2005). In unison, these effects provide more secure positions in the product markets which may justify small overlap in external technology search with more focused competitors.

Finally, a diversified brand portfolio can prove to be beneficial from cost-efficiency considerations, too. Cohen and Klepper (1996) find that the returns to R&D are closely dependent on the range of a firm’s output because fixed costs related to R&D activities can be better spread on more business applications and market niches. As a consequence, firms with more diversified brands and product portfolio are in a more advantageous position vis-à-vis rivals with narrow product space, because they can devote either more budget to, or expect better cost efficiency *ex post* in external technology links. In addition, if a general purpose technology (Arora and Gambardella, 1994) is the objective of external technology cooperation, it might also boost a quicker recovery of the development cost according to wider potential application opportunities by brands in different product categories. More degrees of financial freedom will eventually pose more pressure on less capable competitors and expel them from key ETS locations. Further, technology producer organizations tend to provide their in-house developed technologies to increase earnings, but it can enhance production efficiency of incumbents in their home sector (Fosfuri, 2006). Therefore, they prefer to find buyers in geographically distant markets or in different product categories

(Arora et al., 2001). Thus, an organization with a diverse set of brands can take advantage on this opportunity augmenting the divergence of its ETS locations.

> HYPOTHESIS 4. *Firms with more diversified preexisting stock of trademarks will have less intensity of geographic overlap in external technology search locations compared to rivals.*

4. Data and methodology

Sample construction

To test these ideas, we resort to the Security Software Industry (SSI) which has its technological origins in the 1970s due to large investments made by the US government in military projects related to security of data transmissions. As a result, a sound scientific background in cryptography and encryption emerged through the involvement of large ICT firms and university departments that manifested in a historical, USPTO-registered patent stock. This process created a publicly available source of knowledge spillovers that benefited enormously the birth of the SSI with a clear commercial focus at the turn of 1980s and 1990s. At that time, several favorable environmental factors supported the industry evolution such as the fabulously growing PC market, the development of the Internet accompanied with the need toward secure Internet-based financial transactions. Consequently, the worldwide sales of security software products between 1997 and 2002 tripled from USD2.2 billion to USD6.9 billion (International Data Corporation 2000 and 2003). Rising demand enlarged the spectrum of market supply which embraces not only basic products of encryption such as firewall or antivirus programs, but comprehensive and advanced security services linked to protection of operating systems and applications, network security management packages, and sensible data and hardware protection (Giarratana and Fosfuri, 2007). The emergence of new market niches altogether with fierce market competition spurred widespread trademark issuance in SSI that enables firms to forge brand protection, to take advantage on reputation of superior product quality, and to forge customer loyalty, which ultimately enhance the commercialization potential of the trademark issuer. Table 1 exemplifies the various motives and applications of trademark issuance in the sector. A notable technical characteristic of the industry has to do with the mathematical crypto algorithm that is the principal component of a security software product through transforming plain text data into cipher text, and what it can be strongly protected by patents. The task of crypto algorithm is to execute the encryption and decryption processes of the data, and its quality in terms of security level and speed of mathematical calculations is a decisive factor to provide competitive advantage for the owner organization (Giarratana, 2004). For instance, the US Patent 5,768,373 filed on May 6th 1996 by Symantec Corp. is directed toward providing a secure method to access data when the user has lost or forgotten the user password. The patent description employing several block diagrams explains that the decryption of an access key gives access to data and that two encrypted versions of the access key are created. If the password is forgotten, access to data is accomplished by decrypting the second encrypted version of the access key with the private key from the public-private key pair which is required to be stored in a remote site. A further illustrative example is the US Patent 6,141,420 filed by Certicom Corp. in January 29th 1997 which applies an elliptic curve cryptosystem method instead of integer calculus, performing the encoding-decoding process quicker and requiring less computer space expressed in bits (Giarratana, 2004).

Insert Table 1 about here

There are several industry traits that emphasize the importance of external technology search for security software manufacturers. First, product innovation plays a major role accompanied by the proliferation of lucrative new product categories (The Economist, 2002). Second, it is a technology-based industry with continuous innovation where the complexity of a security software system requires incorporating problem solutions from distinct technological areas, for instance mathematics, hardware engineering, software development and network design (Giarratana, 2004). Third, competition is intense implying low entry barriers, paucity of first-mover advantages for survival and a high hazard rate of firm exit (Giarratana and Fosfuri, 2007). Therefore, we believe that the worldwide SSI proves an ideal setting to study firms' collocation patterns of external technology search.

To verify the hypotheses, we constructed a longitudinal data set tracing SSI firms' locations for acquisitions and strategic technology alliances on a global base. We found out the population of SSI organizations via security software product introduction data from Infotrac's General Business File ASAP and PROMT database (former Predicast) that, from a large set of trade journals, magazines and other specialized press (e.g. eWeek, PC Magazine, PR Newswire, Telecomworldwire), reports several categories of events classified by industrial sectors. This data source is the more recent version of the former Predicast database and was applied in various studies (e.g. Pennings and Harianto, 1992; Fosfuri, Giarratana and Luzzi, 2008). We have searched for all press articles that reported a "Product announcement", a "New software release" and a "Software evaluation" in SSI at SIC Code 73726 (Encryption Software Sector) from 1980 to 2002. These steps determined that the first product had been introduced in 1989.

Prior contributions point at the pivotal role that acquisitions (Haspeslagh and Jemison, 1991; Hitt el al., 1996; Pisano, 1991; Vermeulen and Barkema, 2001) and strategic technology alliances (Dussauge, Garrette and Mitchell, 2000; Hamel, 1991; Kumar and Nti, 1998; Lane and Lubatkin, 1998) can play when external sources of knowledge and technology have become relevant. Therefore, we take into consideration these inter-organizational mechanisms to study external technology search patterns of firms. Resorting to the same Infotrac database, we downloaded all the articles for SSI firms that report an acquisition and an alliance event under SIC 73726. For all types of events, we carefully read the text of business news, and removed the equivocal events from the sample. Considering alliance texts, we selected only those events for the variable strategic technology alliance where partners are involved in combined innovative activities or exchange of technologies (Hagedoorn and Duysters, 2002). Hence, equivocal cases or marketing alliances were excluded. It is worth noting that acquisitions are often used to increase CEO power or to penetrate in a new and untapped geographic market (especially at older sunk-cost industries). Notwithstanding, an acquisition in SSI has primarily a technology or knowledge acquisition orientation, as target organizations can have a valuable (protected) technology or can employ skilled software engineers. For instance Cisco Systems that is also heavily interested in the network, content and web security business uses a considerable part of its profits to purchase firms with R&D capabilities (Shapiro and Varian, 1999).

We studied all the security software firms that realized at least one external technology search during the 4-year spell 1999-2002. By this period, SSI developed to a mature industry where the use of the above three mechanisms became ubiquitous. The sample consists of 119 security software firms that are undoubtedly the leading players in the industry. The panel data structure tracks a dynamic link between firm resources and location patterns that eliminates any potential endogeneity problems. In constructing the database, we made firm dyads as the unit of analysis which was motivated by the following reasons: it captures a firm's relative position, it provides a consistent comparison across organizations, and it efficiently reflects the competitive engagements of firms (Alcácer, 2006; Baum and Korn, 1999; Chen, 1996; Sirmon, Gove and Hitt, 2008). Table 2 offers descriptive statistics on the different types of external technology search that the sampled firms realized across the whole study period.

Insert Table 2 about here

Dependent variable

Following Alcácer's study (2006), we apply a similar measure in its construction for our dependent variable. This location index (LOCI) allows for comparing the geographic convergence or dispersion of ETS networks to any two sample firm (*i* and *j*) in giving an in-between value of complete coincidence or total dissimilarity. The sign i_t' is a 1x*n* row vector while j_t denotes a *n*x1 column vector. Each element, of i_{tl} or j_{tl} takes on either 1 or 0, depending on whether the given firm has realized an ETS activity in location *l* at time *t*. From the viewpoint of firm *i*, the LOCI_{ijt} measure is a percentage value of ETS locations overlapped by both firms in year *t*, mathematically:

$$\text{LOCI}_{\text{ijt}} = \frac{i_t^{'} * j_t}{i_t^{'} * i_t} = \frac{\sum_{l=1}^{l=n} i_{tl} * j_{tl}}{\sum_{l=1}^{l=n} i_{tl} * i_{tl}}.$$

The LOCI measure is dyadic by construction and varies theoretically from 0 (dispersion) to 1 (similarity). If the index reaches its maximum value 1, it means that firm *j* explored exactly the same geographical sites as firm *i* in time *t*. In the reversed case, firm *i* and *j* don't share any geographically coinciding locations in their explorative undertakings, and so the index takes the value of zero. Alcácer's index is a quite precise and convenient way to compare the location choices of any two sample firms, as it represents a multidimensional relationship with a single value, and the interpretation is intuitive. Additionally, the index weights only those elements that equal 1, and it is independent of the number of elements in the vectors, in contrast to correlation or covariance which "vary when more null elements are added to the vectors (Alcácer 2006, p. 1461)". Ultimately, the LOCI measure inherently is not symmetric for firm pairs *i-j* and *j-i* owing to the scale applied in the denominator that is always related to the focal firm. In fact, this feature reflects competitive asymmetry (Chen, 1996) by recording differently the presence in geographic factor markets for participants in a given firm dyad.

To calculate LOCI, first, we had to identify the exact location of all organizations with which the sample SSI firms had ETS links. For firm *i* in year *t*, we considered the acquired firms by *i*, and its technology alliance partners. Second, we also included sample firms' headquarter locations to be able to operationally compare firms with the LOCI measure for those years when they don't realize ETS, and to account for the importance of local search for knowledge spillovers (Jaffe, et al., 1993; Tallman et al., 2004). Third, we had to devise an appropriate policy with regard to possible geographic divisions because isolation patterns of external technology search grasped by the location index might be sensitive to units of geographical classification. Let's consider a South-Californian security software maker that locating ETS only in a geographically limited territory, for example in the neighbouring counties, might obtain higher and higher values for LOCI with respect to the same rivals if one increases the size of geographic units. As a consequence we apply a similar geographic gradation to that of Alcácer (2006), for which we determine the value of LOCI for three geographic levels: clusters, countries and economic regions. Operationally, clusters are equal to US counties, or equal official geographic units outside of the US; country level refers to independent states or US states; and an economic region is related to a group of countries that culturally, economically share common traits. The involvement of the spatially greater regions can amplify our understanding on ETS location patterns as country level can underestimate the extent of geographic dispersion of an ETS network. In addition, a cluster-level measure for LOCI can provide a more sophisticated insight of location choices because some firms may concentrate external technology search to a geographically limited area. We identified all actual geographic locations properly through the Geographic Names Information System for US locations and the Getty Thesaurus of Geographic Names for foreign, non-US locations. Finally, we calculate the LOCI value for all geographic levels considering the type of ETS activities separately (acquisition, strategic technology alliances). Consequently, we obtained six LOCI measures depending on geographic gradation and activity type. Table 3a summarizes the dyadic and firm level location indices by the type of ETS activities (acquisition and strategic technology alliances) calculated at the cluster, country and regional levels, whereas Table 3b shows the geographic profile of ETS channels at the country level. This latter table reveals that the US-state California was the most popular location for the establishment of any type of ETS links.

Insert Table 3a and 3b about here

Estimation procedure

We hypothesize that the location of boundary-spanning external technology search vis-à-vis rivals is generated by the function $LOCI_{ij} = f\ (X_{ij}\ ,\ \beta)$, where the dependent variable is the location index for the convergence or dispersion of technology exploration networks, X_{ij} is the set of explanatory dyadic variables, and β is a vector of parameters to be estimated. One econometric challenge has to deal with the fact that dyadic data are assumed not to consist of independent observations, but rather have varying amounts of dependence on one another which can lead to autocorrelation in the error terms (Krackhardt, 1988). The lack of such independence is best illustrated by a firm that purposefully decides to separate its ETS allocation from the rest of competitors due to some unknown reasons, whereby a chain of positive autocorrelation for all dyadic observation related to the deviating firm is introduced that can generate small standard errors and thus inflated *t*-statistics (Alcácer, 2006). Additionally, the existing row or column interdependence can bias ordinary-least-squares (OLS) tests of significance (Krackhardt, 1988). To deal with this problem of bias, we therefore use a method based on Krackhardt (1988), who proposes a nonparametric solution called the Quadratic Assignment Procedure (QAP) that provides unbiased tests for regression coefficients. The QAP algorithm proceeds by first performing an OLS regression on the original data set. Then the rows and columns of the dependent variable matrix are permuted to provide a new, scrambled matrix. The OLS regression calculation is then repeated with the new dependent variable. The program stores coefficient estimates and R^2 values. Next, another permutation of the dependent variable is drawn that is subjected to a new OLS regression whose coefficients and R-square values are again stored. This permutation-regression step is repeated 500 times that yields a reference, empirical sampling distribution for the stored betas of independent variables under the null hypothesis of no relationship between the independent variables and the dependent variable. In the end, one can compare each actual coefficient of the first OLS regression with the empirical distribution to reject the null hypothesis at an extreme high or low percentile.

Independent variables

We controlled for upstream intellectual property right-related assets of firms with two variables. The *Firmpatent* variable is defined as the count of the cumulative number of unexpired patents granted to an SSI firm. Patents have been used extensively in the innovation literature to measure technological capabilities (e.g. Henderson and Cockburn, 1994), and provide externally validated measures of innovative success that closely resonate to a firm’s level of technological competence (Narin, Noma and Perry, 1987). This time variant variable is lagged by one year, depreciated with a usual perpetual inventory formula of 15% and was downloaded from the US Patent and Trademark Office (www.uspto.gov). Furthermore, we only considered the fundamental technological classes pertaining to the SSI which include the 380, 382, 705, 709, 713 and 726 3-digit patent classes (Giarratana, 2004). The *Patentgenerality* variable strictly builds upon the patents applied at the former measure. We calculate the cumulative number of the annual average number of claims based upon the same patents that an SSI firm obtains in the same strategic patent classes. This variable is time variant, lagged by one year, depreciated in the same manner and comes from the USPTO database as well.

We apply two trademark-related measures of theoretical interest to grasp the downstream intellectual property right strength of our sampled firms. Like at patent records, we resorted to the USPTO database and downloaded only the annual number of LIVE software trademarks. To obtain the stock of trademarks for our focal organizations, we followed the method by Fosfuri et al. (2008) in which we applied a search algorithm through strings of words to the text of the trademark description of goods and services. We call this measure *Livetrademark*. The last core variable, *Trademarkdiversification* is the annual average number of three-digit US trademark classes from the yearly set of LIVE software trademarks of a firm. Both trademark variables are time variant and lagged by one-year.

Controls

We introduce a set of controls that may be alternate explanation for firms' external technology search behavior. Experience in the market is captured by the number of years a firm is competing in SSI (*Age in market*) where it enhances firm survival (Giarratana and Fosfuri, 2007). This variable is the difference between a firm's entry year and the current year. We account for any possible distorsion of a firm's scale through the variable *Sales in* *software business* which is the share of LIVE software trademarks on the total LIVE trademarks multiplied by the firm sales (the source of this latter: Bureau Van Dijk's Osiris). Higher extent of industry competition at firm entry was found to deteriorate survival options for security software makers (Giarratana and Fosfuri, 2007). To control for different industry conditions at the time of entry we employ a measure of organizational population density at the time a firm enters the market (*Density delay*), as initial competition conditions can exert lasting effects on the extent of overlap in technology search locations. Past literature studied the magnitude and sustainability of first-mover advantages (Lieberman and Montgomery, 1988). Early entrants might benefit from first-mover advantages through economies of learning, established reputation and the existence of switching costs that is common in the entire software industry (Torrisi, 1998). Such favorable conditions might influence technology search channels when permitting first-movers to oversearch their rivals. Accordingly, we insert the dummy variable "*Pioneers*" in our estimations if a firm entered in the formative period 1989-91, the first 3 years of the industry. Firms' core business can influence the way how ETS is spatially distanced or converged from competitors because a firm's core sector could exhibit common patterns in searching external knowledge and technology. Moreover, SSI can also host *de alio* companies as implied by Giarratana (2008). Hence, we employ three dummies that address the core business of the sampled organizations: *Hardware* (SIC code 357), *Software* (SIC 737), or *Electronics* (SIC 359-370). Data on firm core business was taken from Bureau Van Dijk's Osiris and Hoover's. In addition, we implement in the QAP regressions two geographical dummies that take the value 1 if the headquarter of a firm is situated in *North America*, or in *Europe* (0 otherwise). Dummies on firms' technological background and place of origin were also introduced by Alcácer (2006) in its study on subsidiary location choices.

Given that we employ a dyadic dataset, all independent and control variables similarly to the dependent variable are also dyadic: either differences from the focal firm's perspective, or dummies with a value of 1 if both firms in a given dyad share the same feature described in the discussion of the proxy variable. To construct the database, we applied a pairing algorithm using the statistical software package *R*. The data table on which we perform the regressions consist of 56644 lines according to the number of firms involved and the time span considered. Table 4 provides the basic descriptive statistics for the independent variables and controls.

Insert Table 4 about here
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5. Results and discussion

We run regressions using Multiple Regression Quadratic Assignment Procedure with the above covariates. Table 5 presents results that are shown in three main sets. Sets reflect how the dependent variable formation is affected by the type of geographic classification applied. Each column within a set displays results related to the specific sort of external technology search mechanism: acquisitions (AQU) and strategic technology alliances (STA). The dependent variable is the location index (LOCI) of external technology search whose construction varies either by ETS type, or by geographic unit. To begin, we describe the effect of our core variables on the isolation of those ETS types where they display significant impact. Taking into consideration the conceptualization of the hypotheses, one must expect negative signs for the variables of theoretical interest.

Insert Table 5 about here

Firms with large preexisting stock of industry-core patents isolate acquisitions vis-à-vis industry competitors when exhibiting negative and significant values at conventional levels only for these activities. This pattern of *Firmpatent* holds the same for all geographic areas. A more general preexisting stock of industry specific patents expands the geographic isolation of strategic technology alliances and acquisitions. Interestingly, the effect of *Patentgenerality* is slightly stronger in case of placing the level of investigation to the regions. *Livetrademark* is also an important IPR-related covariate as it enhances isolation for both types of ETS. An exception emerges only because its effect for acquisitions at cluster level is insignificant. The last core variable, *Trademarkdiversification* enjoys explanatory power exclusively at acquisitions and mainly at regional level because its effect at cluster and country level is significant only on the margin.

Recapitulating the strongest links for each ETS tie, we can conclude that the isolation of acquisitions is largely supported by all types of intellectual property right. An acquisition is a complex undertaking as it often demands knowledge complementarity and financial power from the part of the acquirer, and the ability to integrate the acquired entity into its organization. The strategic arguments highlighted at patent stock, the absorptive capacity (Kumar and Nti, 1998; Zahra and George, 2002) and the exploitation of synergies arguments at patent stock generality, the financial fit and boosted appropriability conditions mentioned at trademark stock (Fosfuri et al., 2008; Mendonça et al., 2004), and, finally, the organizational routines argument used at the diversity of trademarks promote these findings. Taking a look at Table 5, one can observe that the generality of patent stock and the number of live trademarks are the primary motives for a spatially dissimilar network of strategic technology alliances vis-à-vis rivals. The absorptive capacity with an enhanced ability for differential learning (Kumar and Nti, 1998; Zahra and George, 2002), and the potential for a “connect and develop” strategy (Sakkab, 2002) (ideas mentioned at generality of patent stock), and good prospects for technology commercialization (Mendonça et al., 2004) accompanied by increased financial latitude (Seethamraju, 2003; Smith and Parr, 2000) corroborate such a pattern of behavior. To interpret our findings better, we provide a succinct summary in Table 6.

Insert Table 6 about here

As far as it concerns our control variables, the *Age in market* measure is negative and significant only at acquisitions, and at the country and region level (Model III and V in Table 5). This result suggests that firms in the Security Software Industry with deeper industry experience tend to select geographically more dispersed targets for acquisitions. Although the variable *Sales in software business* in general takes on positive and significant coefficients, its effect on the dependent variables is rather low. Harsher industry competitive conditions at entry into SSI implied by the variable *Density delay* only compel firms to apply a spatially divergent location strategy merely for acquisitions, though with an effect that is only significant considering larger geographic units (Model III and V in Table 5). The dummy for early entrants (*Pioneers*) is not significant in either cases, showing that first-mover advantages in the Security Software Industry do not play any role in developing a geographically dispersed external technology search. Similarities in technological background induce divergence or convergence in locating ETS. For instance, *software* firms exhibit an isolation pattern in ETS which is observable at both types of ETS, but strictly at country and region level (Models III-V in Table 5). Conversely, *de alio* organizations with background in *electronics* choose to converge in locations for strategic technology alliances, though particularly at regional level (Model VI in Table 5). In contrast to company background in software and electronics, *hardware* firms follow neither flocking, nor fleeing with each other in ETS. Finally, security software firms that are originated from *North America* develop a geographically similar network of ETS. This finding is uniform across activity types and geographic units. For example, if both firms come from North America, they increase location levels at country level by 0.32 and 0.17 for acquisition and strategic technology alliances, respectively (Model III and IV in Table 5). European security software markers flock with each other but this pattern is uniquely observable for acquisitions (Model I, III and V in Table 5).

6. Conclusions

According to prior contributions (Chung and Alcácer, 2002; Kim and Kogut, 1996; Rosenkopf and Nerkar, 2001), this research started with the premise that external technology and knowledge search is an important mechanism for firms. However, the geographic isolation of external technology search channels must critically depend on firm resources. In this paper we have investigated empirically the role of upstream and downstream intellectual property right tools on influencing the spatial dissimilarity of ETS networks of firms compared to rivals. Therefore, we studied how much firms share the extent of geographic overlap in external technology search locations given the investments made in patents and trademarks. Our evidence suggests that higher preexisting stock of industry-core patents let firms isolate acquisitions vis-à-vis rivals. The generality dimension is also not negligible as more general preexisting stock of industry specific patents augments the divergence of strategic technology alliances and acquisitions with the strongest effect at regions. It is worth noting in connection with the downstream IPR tool under study that the stock of a firm's live trademarks is also an important IPR-related covariate as it promotes isolation for both types of ETS. However, the diversification of an organization's live trademark portfolio explains the spatial divergence of the acquisition network of firms with respect to rivals only at regional level. We were able to get a more ample picture on location patterns of external technology search through incorporating some control variables into our analysis. Correspondingly, more industry experience and harsher competitive conditions at entry compel firms to select targets for acquisitions with less intensity of geographic overlap vis-à-vis rivals, and similarity in technological background and in place of origin can also influence location decisions for ETS.

The main contribution of our work is that, although there is an ample literature on external technology search channels, it has not been empirically linked to geographic considerations. We provide one of the first attempts to bring together external technology search approaches and the geographic components of firm strategy. Additionally, we found that the strategic decision on ETS location choices depends on upstream and downstream IPR-related covariates. This research adds some empirical contributions, too. First, a notable trait of this study that it jointly involves acquisitions and strategic technology alliances as crucial external knowledge and technology sources for business organizations. Second, we applied a panel dataset that makes possible a dynamic study of firm competences and location patterns, required by past studies (Alcácer, 2006). Third, adherence to the research line hallmarked by contributions from Fosfuri, Giarratana and Luzzi (2008) or Fosfuri and Giarratana (2009) that promote trademarks as strategic assets, we also use it for our purposes. However, we involve not only the pure number of this downstream IPR asset, but we directly measure the diversity dimension offering a value addition.

The findings of this study offer several implications for management practice. The general message of this paper for practicing managers is that firms having IPR-related competences can be better positioned in the quest for external knowledge and technology. It is an important factor to have in mind as there is a strong competition for external partners that are located in a geographically dispersed manner in the environment. Firms better equipped with key IPR assets can themselves set the pace of competition that eventually crowd out rivals from crucial technology input factor markets. Our results stress the indispensable role of internal innovation for firms to be able to approach remote partners that might have different knowledge background. This is underpinned by the significant impact of patent generality which might motivate senior management to develop organization skills with a more ample spectrum. Senior management might also want to develop wide IPR competences because external technology strategies are alternative mechanisms, and the optimal choice for the appropriate one in a given business situation can depend on some idiosyncratic factors to be considered (Dyer, Kale and Singh, 2004). This internal policy can help firms not to be unprepared if it has to opt for any type of external mechanism, because, as our study suggests there is a correspondence between the type of technology acquisition tool and the proper IPR competences. The last implication for management practice refers to boosting organizational ability to issue trademarks and patents. One way is by hiring patent and trademark experts that can shorten the IPR-grant process promoting external technology search.

This study also sends important messages for policy makers. For instance, more able firms in terms of IPR competences tend to source technical diversity through various channels of ETS in which they are willing to make a widespread geographical exploration. This is a good piece of news for economic decision-makers of technologically laggard regions: if those regions are developed with an appropriate economic policy, this creates the opportunity through nurturing local firms with specialized expertise that sooner or later local enterprises can connect to and potentially form part of an industrial network, and consequently profit from technology business with a larger community of firms.

This study is not exempt from limitations. The single-industry nature of data (with limited technology focus) applied in the analyses demands the results to be examined in other technology-based contexts. However, the characteristics of the Security Software Industry like the overall focus on product innovation, the fierce nature of competition and the product complexity of security software systems (Giarratana, 2004) can easily match with other young and technology-based environments. Further limitations rely in the relatively short time window of our study that might be improved in future research.

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Table 1

SSI trademarks with the scope of application filed by prominent security software producers

Objective of the trademark from goods and services heading	Registrant	Filing date	Serial number	Emblematic design or the object of legal protection
Brand protection with logo	Security Dynamics	August 23, 1996	75,154,776	SecurityDynamics
Brand name protection through an image	Symantec	August 27, 1997	75,347,874	SYMANTEC.
Protection of a specific service	Verisign	April 22, 1997	75,279,016	"NETSURE"
Protection of a specific product category	Security Dynamics	January 11, 1996	75,041,170	"SOFTID"
Product/service protection through using an image	Security Dynamics	December 5, 1996	75,208,517	ACE SERVER
Slogan protection	Symantec	April 25, 1997	75,281,282	"VIRTUALLY ANYWHERE"
Logo to provide recognizable designations	Checkpoint Systems	November 14, 1996	75,197,809	

Source: Our collections from the USPTO database.

Table 2

Descriptive statistics on the types of ETS

Type of ETS	N. of firms	Total n. of ETS	Mean	S.d.	Min	Max
Acquisitions	119	178	1,50	3,17	0	22
Strategic technology alliances	119	767	6,45	13,21	0	86

Table 3a

Descriptive statistics on the LOCI measure

LOCI at dyadic level (n. of obs = 119)	Cluster level		Country level		Regional level	
	AQU	STA	AQU	STA	AQU	STA
Mean	0.164	0.193	0.288	0.312	0.359	0.394
S.d.	0.356	0.357	0.435	0.419	0.461	0.440
Min	0	0	0	0	0	0
Max	1	1	1	1	1	1
LOCI at firm level (n. of obs = 119)	Cluster level		Country level		Regional level	
	AQU	STA	AQU	STA	AQU	STA
Mean	0.164	0.193	0.288	0.312	0.359	0.394
Sd	0.146	0.149	0.210	0.202	0.226	0.217
Min	0	0	0	0	0.008	0.017
Max	0.379	0.451	0.528	0.589	0.587	0.661

Table 3b

Geographic profile of ETS activities (at the country level)

Country (or US/Canadian state)	N. of STA	%	N. of AQU	%
California	264	34,4%	77	43,3%
Texas	64	8,3%	6	3,4%
New York	63	8,2%	6	3,4%
Massachusetts	50	6,5%	16	9,0%
Washington	42	5,5%	8	4,5%
Ontario (Canada)	34	4,4%	5	2,8%
Japan	27	3,5%	-	-
United Kingdom	26	3,4%	3	1,7%
Germany	19	2,5%	2	1,1%
New Jersey	16	2,1%	4	2,2%
Colorado	15	2,0%	2	1,1%
Finland	15	2,0%	1	0,6%
Georgia	11	1,4%	3	1,7%
Illinois	11	1,4%	4	2,2%
Israel	9	1,2%	1	0,6%
Sweden	9	1,2%	2	1,1%
Virginia	8	1,0%	5	2,8%
Minnesota	7	0,9%	-	-
France	7	0,9%	2	1,1%
Maryland	6	0,8%	6	3,4%
N. of different locations at country level	51		36	

Table 4

Simple statistics of variables

Independent variables	Mean	S.d.	Min	Max
Core variables				
Firmpatent	21.01	80.04	0	646.84
Patentgenerality	15.35	30.14	0	127.69
Livetrademark	26.83	69.75	0	605
Trademarkdiversification	3.75	1.72	0	5.50
Controls				
Age in market	2.20	2.02	0	11
Sales in softw. business (in th US dollars)	2,174,422	5,540,037	0	55,100,000
Density delay	136.97	35.95	12	256
Pioneers♠	0.05	0.22	0	1
Hardware♠	0.07	0.25	0	1
Software♠	0.82	0.38	0	1
Electronics♠	0.05	0.22	0	1
North America♠	0.94	0.24	0	1
Europe♠	0.03	0.16	0	1

Source. Our elaborations spawn from the use of various data sources that embrace Infotrac's General Business File ASAP and PROMPT, US Patent and Trademark Office, Compustat and Osiris databases.
Notes. ♠ denotes dummy variables.

Table 5

Results of QAP estimation (cluster, country and regional level)

Geographic unit	Cluster level				Country level				Regional level			
Type of search activity	AQU		STA		AQU		STA		AQU		STA	
Models	I		II		III		IV		V		VI	
Core variables												
Firmpatent	-0.0001	(0.026)*	-0.0002	(0.054)†	-0.0001	(0.044)*	-0.0002	(0.122)	-0.0001	(0.090)†	-0.0002	(0.114)
Patentgenerality	-0.0003	(0.028)*	-0.0005	(0.052)†	-0.0002	(0.096)†	-0.0008	(0.028)*	-0.0003	(0.038)*	-0.0010	(0.026)*
Livetrademark	0.0000	(0.254)	-0.0004	(0.004)**	-0.0001	(0.046)*	-0.0004	(0.014)*	-0.0002	(0.014)*	-0.0005	(0.002)**
Trademarkdiversification	-0.0017	(0.096)†	-0.0011	(0.356)	-0.0026	(0.072)†	-0.0004	(0.400)	-0.0032	(0.032)*	-0.0012	(0.408)
Controls												
Age in market	-0.0008	(0.378)	-0.0005	(0.460)	-0.0110	(0.038)*	-0.0063	(0.310)	-0.0120	(0.032)*	-0.0070	(0.318)
Sales in softw. Business	0.0000	(0.010)*	0.0000	(0.082)†	0.0000	(0.014)*	0.0000	(0.102)	0.0000	(0.006)**	0.0000	(0.090)†
Density delay	-0.0001	(0.284)	0.0001	(0.464)	-0.0005	(0.040)**	-0.0001	(0.430)	-0.0005	(0.040)*	-0.0001	(0.388)
Pioneers♠	-0.1155	(0.152)	0.0278	(0.294)	-0.1390	(0.224)	0.0522	(0.348)	-0.1723	(0.176)	0.0257	(0.368)
Hardware♠	-0.0496	(0.352)	-0.0586	(0.252)	-0.0166	(0.472)	-0.0464	(0.430)	-0.0602	(0.422)	-0.0829	(0.286)
Software♠	-0.0447	(0.140)	-0.0429	(0.104)	-0.0897	(0.040)**	-0.0761	(0.026)*	-0.0919	(0.046)*	-0.0695	(0.066)†
Electronics♠	0.1772	(0.110)	0.1792	(0.066)†	0.0597	(0.322)	0.1310	(0.136)	0.2609	(0.088)†	0.3007	(0.032)*
North America♠	0.1787	(0.000)**	0.1135	(0.026)*	0.3159	(0.000)**	0.1715	(0.010)*	0.3930	(0.000)**	0.2201	(0.002)**
Europe♠	0.8834	(0.002)**	0.4235	(0.110)	0.8522	(0.000)**	0.4446	(0.168)	0.8496	(0.000)**	0.4346	(0.152)
Constant	0.0332	(0.004)**	0.1194	(0.094)†	0.0644	(0.002)**	0.2085	(0.092)†	0.0670	(0.000)**	0.2419	(0.032)*
Observations	56,644		56,644		56,644		56,644		56,644		56,644	
e(R2)	0.0288	(0.002)**	0.0440	(0.000)**	0.0568	(0.000)**	0.0604	(0.000)**	0.0747	(0.000)**	0.0729	(0.000)**
e(F)	128.22	(0.002)**	198.67	(0.000)**	260.32	(0.000)**	277.52	(0.000)**	348.83	(0.000)**	339.54	(0.000)**

Notes. Dependent variable: LOCI of focal firm *i* with respect to reference firm *j*, data on dependent variables from 1999-2002. Time-variant independent and control variables are lagged by one-year. † indicates $p < 0.1$. * indicates $p < 0.05$. ** indicates $p < 0.01$. Values in parentheses are pseudo p-values. ♠ denotes dummy variables.

Table 6

Overview of support for the hypotheses in terms of activity type

Type of search activity		AQU	STA	Comments
Hypotheses and core variables				
H1	Firmpatent	Yes	-	
H2	Patentgenerality	Yes	Yes	Strongest effect at regions
H3	Livetrademark	Yes	Yes	
H4	Trademarkdiversification	Yes	-	Full support for regions, otherwise partial

CONCLUSIONS

My Ph.D. thesis work titled by *Three perspectives on the Security Software Industry: resource partitioning, real option, and geography issues* includes three papers each with a unique research idea. In the present, concluding section I review the theoretical framework, the research problem and the findings of each of these articles, and then I provide some common features among them.

The first paper, “Resource partitioning and strategies in the market for technology” addresses an important research question not studied in the management literature so far: how a firm’s strategy in the market for technology is intertwined with firm legitimacy. To theoretically address the research question, I resort to the resource partitioning framework that explains how, in their struggle for survival, organizations naturally evolve towards either specialists or generalists. A generalist draws on a broad resource space, and thus implements a product strategy that attempts to maintain a diversified, multi-niche, product offer; by contrast, a specialist relies on a narrow and focused resource space and applies a product strategy that consists of specializing in a single product niche. Therefore, in this paper I ask whether and how a firm’s position in the resource space conditions its buyer and/or seller role in the market for technology. In the theoretical setting, the resource partitioning model is a suitable tool because it assumes that firms’ product strategy – being the outcome of an evolutionary process - is fixed at least in the short term, and thus an exogenous source of heterogeneity across firms.

The results suggest that specialist organizations, i.e. those that follow a narrow product strategy, are more active as sellers in the market for technology compared to generalists, i.e. those that compete in several product domains. On the other hand, generalists resort more heavily to technology acquisition compared to specialists. The work highlights some understudied facets of the population ecology literature, as it shows that resource partitioning is a framework that could be fruitfully extended to other domains not directly linked to the survival chances of organizations. This work also adds some novel insights to the market for technology literature, introducing a new argument of debate, as it is shown that product strategy influences the role of a firm in these technology markets. Precisely, the underlying link speaks for a direct chain of causation between the product strategy, the type of technology, and the role of the organization in the market for technology.

The second paper is entitled as “Intra-industry diversification through real option lens: real options, option portfolio, and uncertainty in the Security Software Industry, 1989 – 2003”. This research builds strictly on real options reasoning which is a theory that has recently gained importance in the field of management. Applying real options reasoning logic can allow firms to experience a greater variety of opportunities that may provide them flexibility in new knowledge creation. Instead of making a single big bet to capture a business opportunity, the real options reasoning allows firms to fund simultaneously a number of R&D projects thereby positioning them more favorably in existing or potential markets. Using real options, with the same resources to spend, more opportunities can be explored and the firm is able to reduce strategic risks of making commitments. Drawn from the previous scholarly work, I test in this work how two different technological options, namely patents and strategic technology alliances, affect the probability of firm entry in a new product niche.

Empirical evidence from the Security Software Industry demonstrates that separately and in unison (as a portfolio of real options), both types of real options, patents and strategic technology alliances, influence positively intra-industry diversification. However, this latter positive effect of option portfolio on intra-industry diversification is negatively moderated by environmental uncertainty. The study claims several points of novelty. First, the importance of a real option approach is shown for explaining intra-industry diversification that is one of the most important strategies in a Schumpeterian environment. Specifically, it is confirmed that strategic technology alliances and patents hold option characteristics and help firms to realize their investments under uncertainty. Second, the study shows the role of having a portfolio strategy of different active options, and how a portfolio strategy could interact with the level of uncertainty. The conclusion is that a portfolio strategy is effective only if all the real options that constitute it are constantly updated. Since the cost of updating increases with the level of uncertainty, firms could find extremely difficult to maintain an updated option portfolio.

Finally, the last paper, “Location choices of external technology search: the role of upstream and downstream IPR assets” pertains to the knowledge and technology search branch of the strategic management literature. Similarly to the first and the second paper in the dissertation, it is also related to intellectual property rights (IPR). This paper investigates empirically the role of upstream and downstream intellectual property right assets on influencing the spatial dissimilarity of external technology search (ETS) networks of firms. Specifically, I study how much firms share the extent of geographic overlap in external technology search locations given the investments made in patents and trademarks. I posit whether firms are able to influence the intensity of geographic overlap in ETS vis-à-vis competitors, is a function of upstream (patents) and downstream (trademarks) IPR tools that can also vary along a generality (at patents) and a diversification (at trademarks) dimension. When distinguishing firm competences by patent stock, generality of patent stock, stock of live trademarks, and diversity of live trademark stock, I obtain that all IPR-related covariates influence the spatial isolation of ETS to a greater or smaller extent.

The main contribution of the work is that, although there is an ample literature on external technology search channels, it has not been empirically linked to geographic considerations. This research provides one of the first attempts to bring together external technology search approaches and the geographic components of firm strategy. Additionally, I found that the strategic decision on ETS location choices depends on upstream and downstream IPR-related tools. This research adds some empirical contributions, too. First, a notable trait of this study that it jointly involves acquisitions and strategic technology alliances as crucial external knowledge and technology sources for business organizations. Second, a panel dataset is applied that makes possible a dynamic study of firm resources and location patterns, required by past studies.

Overall, the three papers represent strong contributions to the literature on technology trade, real options and geography of external technology search. My objective was always to consciously develop the theoretical background, and to appropriately introduce the state of the art on the present stance of the literature. In each case I have tried to select prudentially the appropriate methodology, for instance the Poisson models at the first paper, or the quadratic assignment procedure at the last article. A common feature of all papers in the dissertation is the use of panel datasets that permits the possibility to draw more reliable results on the hypothesized relationships under study. The test bed is another common link among the papers. The Security Software Industry is a very interesting environment because it is a high technology and fast moving industry – similarly to the laser, semiconductor and biotechnology industries studied widespread in the management literature. Therefore, conclusions drawn upon this sector might bear with more potential of generalization in terms of the results achieved.