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The Appropriation of Value from Knowledge: Three Essays on Technological Discontinuities, Market Entry, and Patent Strategy

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ABSTRACT

Knowledge accumulation and protection are critical considerations of the firm. How does the capability to appropriate value from knowledge affect firm strategies in the industries? To answer this question, I develop a new theory and evidence to argue that appropriate value from knowledge is a central consideration in firms' capabilities and decisions to deal with technological changes and intellectual property issues. In particular, I examine the relatedness of products and markets, the strategic uses of patents, and how firms can successfully adapt to concerns regarding technological changes and intellectual property leakage. Throughout my three dissertation chapters, I find evidence that the capability to appropriate value from knowledge can affect how firms behave in consistent and essential ways. These findings provide important implications for knowledge-based views of the firm and strategy-based recommendations in terms of the management of knowledge assets.

Keywords:

Technological discontinuities; complementarity; recombinant capabilities; market experiences, incumbent heterogeneity; market entry; linguistic ambiguity; patent litigation

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CONTENTS

CHAPTER I. INTRODUCTION

I position my research agenda into a broader view of appropriation value from knowledge. I specifically look at firms' corporate strategies in terms of market entry and exit, as well as patent strategies in terms of patent litigation, and show how a firm's capabilities to appropriate value from its knowledge stock affect the above outcomes. Overall, this dissertation aims to demonstrate how a firm's knowledge specificity in different aspects influences its activities.

First of all, knowledge specificity might change the inter-firm relationships during the growth of an industry. Conventionally, the initial stage of the industry presents many entrants, with firms offering many different versions of products competing for market leadership. As the product design stabilizes, division of labor emerges, and focal firms start collaborating with component suppliers and, in general, with complementors to improve production efficiency (Cozzolino & Rothaermel, 2018). In contrast, this pattern of collaboration may change when a transition from an established technology to a new one occurs. When the pattern of collaboration changes, complementors, which generally have well-aligned incentives to work with the focal firm, may rely upon their accumulated knowledge and decide to compete directly with the focal firm itself. Although the competitive paradigm in high-tech industries has been shifting significantly due to the increasing importance of product complementarity, previous studies have emphasized the importance of successful cooperation among complementors in improving the value of each other's offerings in the customers' eyes and increasing the size of the joint profits (Adner, 2006; Adner & Kapoor, 2010), less attention has been given to the possibility that varying degree of product complementarity may exist between complementors and the focal firm and that the extent of complementarity may influence the nature of the relationship. Therefore, the question of how the degree of product complementarity affects the relationships between complementors and the focal firm is worth exploring.

Knowledge specificity may also help incumbent firms to adapt to technological discontinuities. As a technological discontinuity may reshuffle the market, it can provide opportunities and challenges for incumbents. Indeed, a growing body of literature highlights why demand side elements such as preference shifts and new customer segments can be particularly relevant to technological discontinuities. Therefore, examining the implications of incumbents' market-related capabilities in adapting to technological discontinuities may provide a previously less studied role of market-side elements in a firm's entry behaviors.

The proprietary knowledge of a firm should be well protected in strategic ways. A patent is one of the most important forms of intellectual property, but it does not guarantee there will not be knowledge leakage. With patenting, firms need to demonstrate the novelty of their new idea in patent claims and how the new idea is different from relevant existing ideas and products (e.g., Hall, Jaffe, & Trajtenberg, 2005). They may benefit by specifically demonstrating the underlying technology and the novelty of the idea because clearly described patents help firms better claim their knowledge space (e.g., Scotchmer & Green, 1990). However, the context of patent claims naturally creates a tradeoff that firms must navigate. There may be an advantage to having more ambiguous patent claims. The use of ambiguous language in patent claims helps claim a broader knowledge space and leads to the obfuscation of technological information. Less clearly described technologies and their legal boundaries will make rivals less able to decipher the technological nature of the invention and thus less likely to engage in reengineering and predatory actions (e.g., Magazzini, Pammolli, Riccaboni, & Rossi, 2009). Therefore, firms' strategic use of ambiguity in patent claims can protect themselves from valuable knowledge leakage and detection of potential infringement through information obfuscation.

Evidence from Three Essays

In this section, I summarize the main arguments and findings as a preview of the evidence developed in the dissertation. In the first essay (Chapter Two), I argue that market entry depends on the degree of product complementarity. More specifically, firms from a specific product complementary market (i.e., two products value less when they are not consumed together and/or if they cannot be produced without coordination across producers) will have higher incentives to enter the complementary market because it possesses specified knowledge about the market. Thus, I expect a positive relationship between the degree of product complementarity and market entry. Using the event-history analysis approach, I find evidence that firms originating from a specific complementary market are more likely to enter a focal market than firms from a generic complementary market. I also find that possessing more recombinant capabilities facilitates new market entry by allowing the firm to utilize the pre-entry capabilities associated with complementarity. Moreover, the results suggest that entrepreneurial start-ups are more likely to enter than diversifiers. I believe this research can engage with the existing literature by investigating the effect of the relatedness stemming from product complementarity on the incentive for complementors for market entry.

The second essay (Chapter Three) explores incumbent heterogeneity in adapting to technological discontinuities. Because market legacy helps a firm better identify the needs of the new set of customers, which is essential in successfully providing attractive products, I expect that an incumbent's market legacy may help them adapt better to technological discontinuities. Specifically, I discuss reasonings from the capabilities to do ongoing experimentation to identify customer needs in the new application areas (Danneels & Sethi, 2011), generating and maintaining trust with customers, and easier coordination with the upstream and downstream environment (Aggarwal & Wu, 2015), all of which can be necessities for new product market entry. In a sample of computer printer firms that covered three technological generations, I find evidence that incumbent firms with previous experience with a particular market will be more likely to enter the new technological generations that share a common set of customers during technological discontinuities. I also find that incumbent firms will be more willing to explore multiple technologies to address customer requirements if they have superior market capabilities because of reduced uncertainty from the market side. Besides, I find that previous experience with a particular market of an incumbent also increases the likelihood of survival in the new market that shares a common set of customers. The findings of our study advance research on technological discontinuities and point to the need to more systematically consider market legacy as an essential factor affecting incumbent firms' market entry decisions by deploying their previous market experiences in the new technology market to sustain competitive advantage.

In the third essay (Chapter Four), I study the strategic use of linguistics in the context of patent litigation in which firms may engage when patents do not well protect their knowledge and when they are detected potential infringement upon other firms' patents. I argue that firms face the challenge of striking a balance between being specific and ambiguous in constructing their patent claims. On the one hand, being specific in communicating the underlying technology in patents helps firms claim the knowledge space they occupy and defend better in court (e.g., Kitch, 1977; Somaya, 2012). On the other hand, disclosure of clearly described inventions may not only lead to potential knowledge leakage and provide clues for competitors to do reverse engineering and keep track of the technological development of the focal firm (Magazzini et al., 2009) but also alert competitors of the potential to claim infringement (e.g., Polidoro & Toh, 2011; Somaya, 2003). Therefore, firms may be concerned with communicating these patent claims in such a way as to disclose clear information that can be easily understood by competitors so that they can keep track of the technological development and do imitation or detect potential infringement. I expect that higher levels of patent claim ambiguity will be associated with a lower likelihood of the focal firm being named both a plaintiff and a defendant in a patent infringement lawsuit. Still, conditional on this occurrence, the focal firm will be less likely to win.

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CHAPTER II. HOW FRIENDS MAY BECOME FOES: THE ORIGINS OF MARKET ENTRY OF COMPLEMENTORS IN NEW TECHNOLOGY GENERATIONS

ABSTRACT

While previous management studies suggest that product complementarity may provide an essential mechanism in firms' market entry behaviors, we still do not know whether this relationship may hold in industries characterized by discontinuous technological generations. In this study, we suggest that changes in technological generations are a critical source of misalignment among complementary firms by focusing on the entry decisions of complementary firms. Using a unique dataset drawn from the computer printer industry, we found that firms in a specific product complementary market, vis-à-vis a generic market, have a higher likelihood of market entry into the focal industry characterized by multiple discontinuous technological generations. More importantly, the empirical analyses suggest that acquiring recombinant capabilities facilitates market entry by allowing the firm to utilize the knowledge associated with complementarity. In addition, the value of knowledge by specific complementors is more significant under stable periods.

Keywords:

Complementarity; market entry; knowledge accumulation; generational technological change; recombinant capabilities; external environment

INTRODUCTION

Scholars of innovation and industry evolution have documented how inter-firm relationships regarding competition and collaboration may change as their industries grow (Brandenburger & Nalebuff, 1996; Speckbacher, Neumann, & Hoffmann, 2015). The initial stage of the industry presents a lot of entry with firms offering many different versions of products to compete to be the market leader, while with continued market growth, subsequently, entry slows and the diversity of competing versions of the product decline, meanwhile, firms start to collaborate to achieve efficiency (Cozzolino & Rothaermel, 2018; Klepper, 1996). We suggest that new technology generations can reshuffle the market in such a way that market players may change the nature of their relationships. In this paper, we consider the implications of the collaboration and competition aspects of the relationships between complementors for the firm's incentives for market entry. We argue that recognition of the interdependence of complementors' relationships suggests that complementor firms that generally have well-aligned incentives can accumulate relevant product knowledge and incentives to compete with their complementors.

In various industries, complementors play a crucial role in developing and commercializing complementary products (Mantovani & Ruiz-Aliseda, 2016; Yoffie & Kwak, 2006). For instance, computer hardware is useless without software applications, electronic vehicles require electronic charging stations, and printers can only function when equipped with toner cartridges. While much scholarly efforts have been focused on the importance of successful cooperation among complementors in improving the value of product quality and in increasing profits (Brandenburger & Nalebuff, 1996; Adner, 2006; Adner & Kapoor, 2010; Gawer & Cusumano, 2002), not much attention has been given to whether the level of product complementarity may vary depending on technologies and how these different levels of product complementarity may affect the pattern of collaborations among firms. For instance, when firms need to cope with distinctive technology transitions in the industry, they may recognize opportunities of changing their market positioning strategies and decide to directly compete with their previous complementors by replying upon their accumulated knowledge in the industry. This gap motivates our overarching research question, namely: how the degree of product complementarity affects the relationships between complementors and the focal firm?

The strategic management literature on market entry has barely examined market entry by complementors.[1] Because complementors share the aim to expand their mutual market, they often overestimate the common interest with complementors while underestimating the potential for conflict (Yoffie & Kwak, 2006). However, even these complementors may experience situations in which their interests are misaligned, such as disagreements over pricing, failure to synchronize their productions, different timing to release new products, and bargaining over value-captures (Casadesus-Masanell & Yoffie, 2007). In such situations, the benefits from cooperation may get relatively smaller than those from the competition, making complementors enter the market as competitors. This gap in the literature motivates our first research question: how the degree of product complementarity affects a complementor's decision to enter the focal market?

Lastly, as firms' prior experience and pre-entry knowledge may explain the entry behaviors and post-entry performance of these firms (e.g., Helfat & Lieberman, 2002; Cattani, 2005; Agarwal & Shah, 2014; Adams, Fontana, & Malerba, 2016), we further examine the role of pre-entry knowledge and prior experience in the context of the market characterized by uncertainty.

[1] A set of studies have considered instead the possibility of entry by the focal firm into a complementary market, especially in platform-based settings (Gawer & Henderson, 2007). For example, platform leaders make decisions on whether to enter and compete with their complementors based on their knowledge of the demand for complementary products (Jiang et al., 2011). As a consequence, many complementors that were providing successful products were displaced from the market not by their counterparts but by the platform owner who entered the complementary market later (Zhu & Liu, 2018).

We tackle all these research questions by focusing on the product market entry decision by complementary firms into the focal market. We first propose that entry depends on the degree of product complementarity. Specifically, we consider two products to be *specific complements* if they value less when they are not consumed together and/or if they cannot be produced without coordination across producers (Jacobides, Cennamo, & Gawer, 2018). We argue that firms from a specific product complementary market would have higher incentives to enter the complementary market because it possesses specified knowledge about the market. In contrast, when two products are *generic complements*, in other words, their joint consumption generates greater utility than separate consumption, but they can be used and produced separately (Teece, 1986), a complementor may only possess limited relevant knowledge of the complementary market and has lower incentives to enter.

Furthermore, relying upon evolutionary theory (Nelson & Winter, 1982) and the resource-based view of the firm (Amit & Schoemaker, 1993; Barney, 2001; Rumelt, 1984; Wernerfelt, 1984), we propose that the extent to which a firm can apply its prior experience to the new complementary market hinges on the degree of product complementarity, which is crucial in affecting the firm's entry decision. We argue that a firm's capability to recombine its prior knowledge of complements is critical to strike a balance between what is needed in the new domain and what is in excess (Xiao, Makhija, & Karim, 2021). One firm's recombinant capability, defined as being able to understand the linkages among elements in different domains and recombine these elements into innovations, will moderate the effect of product complementarity on entry into the focal market. We also propose that the value of knowledge accumulated by specific complementors will depend on the external environment in relation to its stability and uncertainty.

Our empirical analysis is carried out in the computer printer industry, whose evolution has been characterized by intense competition between focal firms and entrants from many complementary markets, such as ink cartridges, computers, and industrial copiers. The findings in this study largely support our expectations. Firms from a specific complementary market, compared to those from a generic complementary market, are more likely to enter the printer market. The positive association between specific complementarity and the likelihood of market entry will increase with the level of recombinant capabilities a firm possesses. We also found that specific complementors are less likely to enter the focal market during periods of uncertainty. Our study provides insights for both scholars and practitioners to better understand the underlying relationships between firms in the focal market and their complementors.

THEORY DEVELOPMENT

The strategic importance of complementors

Economists and management scholars have extensively acknowledged the importance of two types of firms: 'friends' firms whose cooperation can be beneficial and 'enemies' firms that should be competed against (Schumpeter, 1942; Walley, 2007). Related to this phenomenon is the role of complementors as firms offer new products or services that are increasingly dependent on other offerings to create additional value for the customers (Reisinger, Schmidt, & Stieglitz, 2021; Schilling, 2003). However, even though complementors have been increasingly studied in recent years (Adner & Kapoor, 2010), we do not know much about under which condition these friendly complementors may become enemies.

We define complementary products as those products that are used as inputs to an assembly sector (Carr & Karmarkar, 2005) or components in a multi-component product system (Matutes & Regibeau, 1988), or that enhance the value of another product by end-users. Although the notion of complementarity in the management literature has been defined in various ways, there are largely two approahces in deterining the nature of underlying interdependencies among firms: 'functional interdependence' and 'consumer usage' approaches. Technological and functional interdependence perspective suggests that complementary products must be understood as a set of parts (i.e., components) of a product system (Binken & Stremerche, 2009). In contrast, scholars who emphasize the role of users focus on the added value that complementary products can generate to those who employ them. For instance, a complement to a focal product can make it more attractive (Brandenburger & Nalebuff, 1996) or enable users to increase the benefit from joint consumption (Carlton & Waldman, 2002). As it is critical to examine the relationship between complementarity and market entry, we take an encompassing view of both the 'functional interdependence' and 'consumer usage' approaches in this study.

Furthermore, we define *complementors* as specialized firms that independently provide complementary products or services directly to mutual customers (e.g., Yoffie & Kwak, 2006). Although product complementarity can range over a continuum, previous scholars have often dichotomized the types of complementarities. For instance, while some products may increase the functionality of other products (i.e., a specific complementarity), some other products are necessary to have their functionality (i.e., a strict complementarity). In this study, we combine these two types of complementarities and define products to be *generic complements* when their joint consumption generates greater utility than separate consumption, but these complements can be consumed jointly with other products as well (Teece,1986). There exist several examples of these generic complements, such as mobile phones and network service, paper-making machines and pollution control devices, or airplane purchase and service contracts (Aribarg & Foutz, 2009; Bhaskaran & Gilbert, 2005; Costa & Dierickx, 2005). In contrast, we define products to be *specific* *complements* when their joint consumption generates greater utility than their separate consumption (Jacobides et al., 2018). Specific complementarity might be stronger as "*A does not 'function' without B*" or weaker as "*the value of A is maximized with B.*" Henceforth, we employ these definitions to investigate how the entry of a firm into the focal market is differentially affected by the type of complementarity.

Knowledge accumulation by specific complementors

Firms would benefit more from having additional coordination efforts in technological and functional alignments with *specific* complementors than *generic* complementors. On the one hand, as specific complementors provide products that are closely related to those of the focal firms technologically and funationally,[2] these complementors become strategically more critical to the focal firms. On the other hand, compared to firms with generic complementors, specific complementors are more likely to experience difficulties from breaking their established relationships with the focal firm due to the high level of customization in introducing new products or in capturing value from customers (Jacobides et al., 2018). However, when a transition from an established technology to a new one occurs, this relatively stronger collaboration pattern among specific complementors may not hold.

First, knowledge bases of specific complementors might differ from generic complementors. Specifically, firms that originate from a specific complementary market are more likely to possess resources that are a "good match" to the required resource profile of the focal industry. Drawing on the early movers' advantage perspective, these firms choose to enter an

[2] For example, the president of Sony Computer Entertainment of America, Kazuo Hirai, emphasized the importance of software applications to video game consoles by staying "Software is the King." HBS Case study # 9704488, 2004, Note on Home Video Game Technology and Industry Structure, Peter J. Coughlan.

industry early because they can exploit prior production and market experiences to progress down the learning curve (Rosenbloom, 2000; Klepper, 2002). In addition, these firms gain further competitive advantage from improving the performance of their products or reduction of cost (Argote, 1999; Lieberman, 1989). As the extent to which firms can gain a competitive advantage is a function of the likelihood that they can exploit and increase the potential for learning (Adner & Kapoor, 2010), by progressing down the learning curve after entering, these firms that originate from a specific complementary market may possess different incentives than firms with generic product complementarity and may benefit more from their market entry.

Furthermore, firms with specific complementarity may increase their product variety through the entry because complementary products can enhance the firms' value to the focal market. For example, confronted with a low barrier to entry, high competition, and a decline in profit margin after the emergence of the dominant design in the personal computer market, HP attempted to re-assert its leadership by entering the printer product market (Langlois & Robertson, 1992; West, 2003; Heeb, 2003). As specific complementary products can generate a higher level of technological and functional interdependence upon each other, entering a specific complementary market demands the presence of firm-specific assets (Argyres & Zenger, 2012; Qian, Agarwal, & Hoetker, 2012; Williamson, 1985). In particular, market entry incentives are greater when the current market is highly competitive and with a declining profit margin (Cottrell & Nault, 2004; Garud & Kumaraswamy, 1995; Sanchez, 1995; Ulrich, 1995). Furthermore, in the presence of economies of scope, firms may have further incentives to enter the market. For instance, Similarly, Microsoft continued to enhance its value through the development of complements such as the Internet Explorer browser, the Office suite, and Media Player to overcome the obsolescence of the Windows-based operating system. Indeed, scholars have suggested that when firms can benefit from relevant and recurrent use of proprietary know-how or on an indivisible physical asset, product diversification can provide a more efficient mechanism for reducing production costs (Panzar & Willig, 1981; Methe, Swaminathan, Mitchell, & Toyama, 1997). Hence, firms with specific complementarity may have stronger incentives to choose to enter a complementary product market.

When firms seek to strengthen their position vis-à-vis complementors, they can strategically manage their dependence upon and their bargaining powers over their complementors (Brandenburger & Nalebuff, 1997; Gal-or, 2004; Nagarajan & Bassok, 2008; Yoffie & Kwak, 2006). Indded, when incompatible incentives among complementors are so significant, and these firms need to compete for value appropriation, one party may choose to internalize the products by entering the complementary market (Casadesus-Masanell & Yoffie, 2007). For example, Kodak started to manufacture cameras in-house because it could not convince other camera manufacturers to develop specific cameras for their new films. Therefore, to avoid potential threats induced by a lack of compatible coping strategies, specific complementors are likely to be incentivized to enter a market when a transition from an established technology to a new one occurs in the industry. In short, when distinctive technology generations reshuffle the market, specific complementors may become more incentivized to enter the market due to the increased conflicts or misalignment. Thus:

> *Hypothesis 1. Firms from a specific product complementary market, compared to those from a generic product complementary market, have a higher likelihood of entering the focal market in the presence of technological generation change.*

Firm-level contingency: Recombinant capabilities

In the strategic management literature, the recombinant capabilities of firms, defined as the firm's ability to recombine existing technologies to generate further innovations, are a crucial driver of firms' innovative performance (Carnabuci & Operti, 2013; Fleming, 2001; Galunic & Rodan, 1998; Hargadon & Sutton, 1997; Nelson & Winter, 1982). For instance, prior research emphasized the importance of architectural knowledge, a deep understanding of the specific components of each domain and the linkages and interdependences among various knowledge domains (Ulrich, 1995), [3] in recombining technologies from different domains. Because the capability of a firm in mobilizing and employing relevant knowledge is critical in understanding whether the firm will decide to enter the market or not, we propose that specific complementors are more likely to enter the market that is characterized by distinctive technology generations.

First, specific complementor firms have unique benefits to enter the market and launch new products due to their accumulated pre-entry knowledge and experience related to the market. Because these specific complementor firms can redeploy their recombinant capabilities in a new but relevant technological area, they can relatively better be positioned in utilizing their architectural knowledge from a process by which firms 'experiment with' and 'make sense of' unexplored interdependencies among technologies they have not combined before (Carnabuci & Operti, 2013). Besides, by exploring and understanding the causal linkages within and across components in one technological area, these specific complementor firms can better facilitate more prominent understanding of the other related technological areas. To the extent that the generation and renewal of architectural knowledge is a "capability broadening" exercise (Argyres & Silverman, 2004; Laursen & Salter, 2006), firms that possess knowledge about how to combine elements from several technological domains can achieve successful innovation performance (Henderson & Cockburn, 1994; Yayavaram, Srivastava, & Sarkar, 2018). In short, when specific

[3] For instance, Texas Instruments created the spatial light modulator in 1977 by combining micro-electrical and micromechanical components. The result of the recombination created the technology of microelectromechanical systems (MEMS) that has been used in devices such as gyroscopes. In this case, the knowledge about the micro-electrical components and micromechanical components is an example of 'domain knowledge,' whereas the knowledge about MEMS is an example of 'architectural knowledge' (Yayavaram, Srivastava, & Sarkar, 2018).

complementor firms possess recombinant capabilities, they are more likely to enter the market when the pattern of collaboration changes due to the introduction of distinctive technologies.

Another source of benefits for specific complementor firms in their entry decision may come from their superior understanding of the industry compared to generic complementors. Generally speaking, complementor firms can acquire profound knowledge about other firms through R&D, manufacturing, assembling, and marketing process. As these firms possess technological capabilities in fields wider than those in which they are producing, their knowledge boundaries extend above and beyond their production boundaries (Brusoni, Prencipe & Pavitt, 2001). However, because specific complementor firms can better utilize the breadth of their knowledge base but closer to the focal products (Tuna, Brusoni, & Schulze, 2018) and ability to envision and generate novel innovations (Leiponen & Helfat, 2010) compared to less specific but more generic complementor firms, when these specific complementors possess relevant recombinant capabilities, they are more likely to enter the complementary market in which they can launch new products relatively more successfully with less uncertainty. By so doing, these specific complementor firms with relevant recombinant capabilities can not only introduce new products but also gain a higher level of control and bargaining power in the relevant markets. In short, while recombinant capabilities can often lead to successful innovation performance in general, they are more likely to increase the entry behavior of specific complementor firms, rather than generic complementor firms, due to the accumulated pre-entry knowledge and experience. Therefore:

> *Hypothesis 2. The likelihood of entry into the focal market by a specific complementor increases with the level of its recombinant capabilities in the presence of technological generation change.*

Industry-level contingency: Market uncertainty

Another crucial element of the relationship between the types and the value of knowledge accumulation around complementary products and the market entry behaviors of the firms may hinge on the external environment (Agarwal, Sarkar, & Echambadi, 2002; Tushman & Anderson, 1986; Ozalp, Eggers, & Malerba, 2022). The market uncertainty in terms of which technology will become the next dominant design and the source of market success (Klepper, 2002) from evolutionary changes in an industry's life cycle (i.e., during early or later stages) (Eggers, Grajek, & Kretschmer, 2020), may be crucial in the effect of firm knowledge on market activities (Helfat & Campo-Rembado, 2016).

Compared to later stages of an industry's evolution where firms face relatively more stable period with reduced uncertainty (Eggers, Grajek, & Kretschmer, 2020) and thus engage with more routinized and incremental which only requires modifying existing designs and technologies (Abernathy & Utterback, 1978; Breschi, Malerba, & Orsenigo, 2000), firms in an early stage of an industry often experience fierce competition among new technologies, frequently changing products, and emerging market niches that are characterized by high uncertainty (Helfat & Lieberman, 2002; Malerba & Orsenigo, 1999). Both incumbent firms and potential entrants need to cope with highly unstable environment that requires firms' capability to be dynamic and flexible to reconfigure existing capabilities to adapt to new technological and market situations (Cattani, 2006). Besides, new product development and introduction is more uncertain in these conditions as required innovations reside in the knowledge which lies outside of the established practices in the focal firms or even the entire industry. In such an environment that is characterized by tremendous uncertainty, the relative benefits of accumulating deep knowledge that is specific to certain technologies or products may get less pronounced compared to diverse knowledge across a broad spectrum (Agarwal et al., 2002; Gort & Klepper, 1982). In other words, in earlier stages of an industry where various factors are still uncertain, specific complementors with deep knowledge accumulated over the known technologies, products, processes, and demand may become less valuable and hence these firms may get relatively less willing to enter these uncertain markets than generic complementors. Hence:

> *Hypothesis 3. The likelihood of entry into the focal market by a specific complementor decreases during the period of uncertainty in the presence of technological generation change.*

METHODS

Industry context

Our research setting is the computer printer industry, which experienced three product generations during its industry life cycle. When the industry first emerged in the 1950s, the dot-matrix printer was the representative product of impact printers. IBM developed and marketed the first dot-matrix printer in 1957. Throughout the 1970s and 1980s, dot-matrix printers were generally considered the best combination of expense and versatility, and they became by far the most common form of printer used with personal and home computers in computer networks in the 1990s. However, impact print technology had poor print quality and was extremely noisy and costly. Then, non-impact printers gradually took over the market. Inkjet printers were one of the representative products of non-impact printers. The first inkjet printer was developed by Hewlett-Packard (HP) in 1976. In the late 1970s, inkjet printers that could reproduce computer-generated digital images were developed mainly by Epson, HP, and Canon. However, inkjet printers did not gain popularity until the mid-1980s. In the late 1980s and early 1990s, inkjet printers disrupted what was then the dominant design, dot-matrix printing. Inkjet printers ranged from small, inexpensive consumer models to expensive professional machines, but they were not the only alternative to dot-matrix. In the mid-1970s, the minicomputer market was exploding. IBM and Xerox had introduced xerographic laser printers for mainframe computers, but nothing was comparable for the minicomputer market. HP seized the opportunity, and in 1984 they launched the first desktop laser printer, HP LaserJet 8ppm, for the retail market. It was the first laser printer for the mass market after personal computers became more widespread. Other models and laser printer manufacturers, such as Brother Industries or IBM, quickly followed the HP LaserJet printer.

Sample and data source

This study employs a dataset that includes all the firms that were active in the computer printer industry, which means that they produced at least one of the following three generations of computer printers: dot-matrix printers, inkjet printers, and laser printers. The dataset was compiled from multiple sources, including *SpecCheck* (de Figueiredo & Silverman, 2007), *CorpTech* (White, 1998), *WEMA* (Western Electronics Manufacturing Association), and *FCC* (Federal Communications Commission) Database. Specifically, *SpecCheck* provided us a good starting point with the list of firms that were active in the printer industry, although we could only obtain limited information on firms) (143 firms) that entered the laser printer industry from the start of the industry until 1996 (de Figueiredo & Silverman, 2007). To expand this initial dataset, we incorporate information from *CoprTech*[4], *WEMA* and *FCC*[5] Database, which provide us information that covers firm production activities in all three technological generations and a longer time period. We gained information on the firms' name, years during which the firm is producing printer products, generations of printer products, firm incorporation year, industries and products descriptions by year, number of employees by year, firm status by year. By so doing, we

[4] CoprTech, first published in 1986, is best known for its annual CorpTech Directory of Technology Companies. Its database contains information on over 45,000 public and private companies in eighteen industries (White, 1998). Through CorpTech, we could not only get firm production information on dotmatrix printers and inkjet printers, but can also extend the period of observation to 1999.

[5] Through WEMA and FCC, we could not only double-check the information we already gathered but also extend observations of firm production activities until 2001.

were able to include 135 new unique firms (58, 49, 28 unique firms from *CoprTech*, *WEMA* and *FCC* respectively).

To deal with the missing observations and further expand our observation period to the most update, we complemented the above data by manually collecting information from multiple archival data sources, including *UsedPrice.com*, *PCMag*, *Computerworld*, and *InfoWorld.*[6] By so doing, apart from the firms what we already obtained, we were able to include 145 new unique firms from *UsedPrice.com* and 5 new unique firms from the other magazines. Then, we matched the firms in our current dataset with *Compustat Database* and *Orbis Historical Database* (2000-2010) and *Orbis Company Information across the World Database* (2011-2021) to double-check and collect other necessary corporate information, such as the number of employees, countries, SIC and NAICS codes.[7]To acquire patent information of the firms in our sample, we matched them with the *Orbis IP Database* (2000-2021) and identified those that had printer-related patents (i.e., USPC main class indexes within 101, 205, 345, 355, 358, 400, 493, 705) based on the study of the printer history and its technology development.8. For patents filed before 2000 as well as firms that are not found in Orbis Database, we rely on *PatentsView* Database, where patents filed after 1976 can be found by matching assignee names.[9] The final sample includes a total of 428 unique firms (8582 firm-year observations) which include firms that were doing business in the computer printer industry from 1957 to 2021.

6 Using Wayback Machine (https://archive.org/) and searching firm names, we were able to read magazine articles to identify the types of printer products a firm had been producing for each year.
7 We relied on firm names to do matching in multiple datasets. We believe this is a practical and reliable process given the number of the firms in our dataset is not too large.
[8] Specifically, we included 27 main and subclass USPC Index that are closely related to printers suggested by (Hung and Tai, 2016). The detailed list of each USPC is shown in Appendix 1.
[9]We rely on Orbis IP Database and PatentsView Database because we could utilize the advantages of both databases in terms of different year coverage and country coverage.

Dependent variables

The dependent variable is intended to capture whether a firm has entered a new printer market. We consider both possible markets into which a firm could enter (i.e., inkjet printers, and laser printers), and we model the entry decision of a specific firm in a specific market in terms of a discrete-time duration model. A generic firm *i* becomes 'at risk' of entering market *m* when that type of printer becomes first available in the market at a specific time period *t*. Entry occurs in the year in which a firm produces at least one type of printer, and the firm is no longer at risk of entry into that market but may remain at risk of entering other markets to which it has not provided a service yet. The observed events in year *t* are coded as 1 ($ENTRY_{it} = 1$), whereas those not observed by the end of year *t* are coded as 0 ($ENTRY_{it} = 0$). We adjust the entry mode by treating a firm formed by the combination of two existing firms as a new entry. Any market in which either predecessor firm operated is removed from the new firm's risk set.

Explanatory variables

The first explanatory variable is *Complementor*, which would be a categorical variable equal to one if a firm were producing specific complements to a printer, zero if it was a generic complementor, and two if it was not producing any complementary product. There are numerous complementary markets revolving around printers among the list of sectors from which firms at the risk of entering the printer market are diversifying: computer hardware (e.g., displays, modems, plotters, terminal, storage); computer software; printer components; semiconductor; service provider (e.g., mailing, electronics, printing publisher); video games; cameras; photography; office equipment; household audio and video equipment. To classify firms into complementors with different product distance, we adopt multiple ways as robustness checks. First, we treat firms that produce printer components as specific complementors, while computer hardware and software producers, cameras, and photography producers as generic complementors. All the others are coded as non-complementors.[10] We then include computer producers into specific complementors and the results are consistent.

The variable *Recombinant capability* captures a firm's capability to understand the linkages among and combine knowledge elements from various domains. We rely on Yayavaram, Srivastava, and Sarkar's (2018) observation that the extent to which a firm is likely to combine knowledge elements from two domains is the couplings that a firm has between all pairs of knowledge domains in its knowledge space, given the assumption by Fleming and Sorenson (2001) that each patent is a combination of the technologies underlying the domains to which it has been assigned. A firm's coupling between technology classes *j* and *k*, $L_{a,\ j-k,\ t-3\ \text{to}\ t-1}$, can be calculated as:

$$L_{a,j-k,t-3\ to\ t-1} = \frac{n_{jk}}{n_j + n_k + n_{jk}} \quad ^{11} \qquad (1)$$

We use the variable *Period of Uncertainty* to indicate the stability of the external environment. It is a binary variable that equals 1 if the fiscal years are between 1980 and 1992, 0 otherwise. We made the decision of the above year window by drawing insights from the industry history.

[Insert Table 1 about here]

[10] Detailed descriptions of the sectors is shown in Appendix 2.

[11] Note that n_j is the number of firm *A*'s patents that are assigned to class *j* but not to class *k*. Likewise, n_k is the number of patents that are assigned to class *k* but not to class *j*, and n_{jk} is the number of patents that are assigned to both classes. We measure a firm's recombinant capability as the firm's couplings for all printer-related patent class pairs.

Control variables

We account for several factors that affect a firm's likelihood of product market entry. We control for firms' cumulative industry experience to take into account the effect of firms' prior experience at the time of entry. The variable *Organizational experience* is computed as the difference between the year of market entry and the firm's founding year. To capture a firm's market position, we created a dummy variable *Prior experience* that equals one if the firm is producing in the preceding market and zero if not. As we combined inkjet printers and laser printers together in our analysis to account for generation-specific differences, we created a dummy variable for each generation, *Inkjet and Laser*, respectively. For instance, we coded every firm at risk entering the inkjet printer market with *Inkjet* = 1; for those not at risk, *Inkjet* =0. We also include a dummy variable *Incumbent* to indicate whether the firms had experience in producing dotmatrix printer which is a prior technology generation ahead of inkjet and laser printers. *Firm Size* is included by measuring the logarithm number of employees at the time of entry. To take into account the country effect, we included a variable *Japan* to indicate where the firm is located. We also include an industry clock to capture changes in the rate of entry arising since the onset of competition in the mid-1970s.

Data description

We recorded the annual market entries of all the computer printer firms from 1957 until 2021. Tables 2 shows the means, standard deviations, and correlations for all variables and the correlations between the variables. Although many pairwise correlations in Table 2a are significant, there are no critically collinear variables. The highest variance inflation factor (VIF) across our models is 2.14, below the recommended critical level of 10, above which multicollinearity is perceived to be a problem (Neter et al., 1996). To improve reliability in the model estimation, we estimated the models by adding the covariates in sequence one at a time and inspected them for any instability in the coefficients or standard error. We observed no significant changes in the estimates across specifications, confirming that multicollinearity is not an issue.

We observe that 63% of the firms in the sample entered the dot-matrix printer market making them to be incumbents, with 55% entering the laser printer, but only 24% entering the inkjet printer. Regarding complementor firms, 117 firms are specific complementors, 190 firms are generic complementors, and 121 firms are classified as not complementors.

[Insert Table 2 about here]

Estimation methods

To test the effect of product complementarity on the likelihood of market entry, we use discrete-time survival analysis with complementary log-log model (Allison, 1982) to estimate the effect of complementarity on a firm's market entry. We employ the survival analysis model because it is needed to address right-censoring. Using discrete-time survival analysis fits better with the characteristics of our sample. Specifically, the entry in our sample is observed on a yearly basis, and different firms entered in the same year, it violates the assumption of continuous time in semi-parametric survival analysis. From two often used discrete-time models, we choose complementary log-log (proportional hazard) estimation over logistic estimation because market entry events occur in continuous time yet we are only able to observe them in discrete time. The results are robust to discrete-time logistic (proportional odds) model and continuous-time.

Consistent with recent research (King & Tucci, 2002; Dowell & Killaly, 2009), the event of interest is whether a firm starts producing printers for a specific market. We begin our analysis by treating all the printer firms in our sample who exist and have not previously entered a market as potential entrants (i.e., 'at risk' of entering) and 'drop' them from the pool of firms at risk once they have entered a specific market. This methodology allows us to consider the firm observation of the risk of event occurrence in a given year as long as the firm is still alive and has not yet entered the market. The probability that firm *i* entered a market *m* in year *t* is thus defined as:

$$Prob[ENTRY_{imt} = 1] = \Pr[T_i = t \mid T_i \geq t, X_{it}] \quad (2)$$ [12]

RESULTS

Results that show the probability of market entry of the potential entrants are presented in Table 3. In this analysis, we consider entry 'tout-court' without distinguishing between markets, and initially, we included non-complementors from the sample to show the baseline comparison between complementors and non-complementors. Then we exclude non-complementors to be able to compare the entry likelihood of firms from specific complementary markets with those from generic complementary markets.

Model 1 shows the baseline model with the direct effect of product complementarity by including firms that are from a non-complementary market (i.e., the whole sample).. The result suggests that complementors are more likely to enter the focal firm compared to non-complementors ($p < 0.05$). Additionally, we show results in Model 2 which compared the likelihood of market entry of specific complementors and generic complementors to non-complementors, respectively. Model 2 presents that both specific complementors and generic complementors are more likely to enter the focal firm compared to non-complementors ($p < 0.01$). Our Hypothesis 1 claims that firms from a specific complementary market are more likely to enter the compared to those from a generic complementary market. The multivariate estimation result in Model 3 confirm that compared to firms originating from a specific complementary market,

[12] Note that T_{it} is the discrete random variable about the time of entry while X_{it} is the vector of explanatory variables.

firms that originate from a generic complementary market are less likely to enter the focal market ($p < 0.05$). Thus, we found support for Hypothesis 1.

[Insert Table 3 about here]

Table 4 shows the relationship between independent variables and mediating variables. Model 1 considers the interaction effect between recombinant capabilities and product complementarity on entry. Hypothesis 2 suggests that the positive association between specific complementarity and the likelihood of market entry will increase with the level of recombinant capabilities a firm possesses. In line with this hypothesis, the coefficient estimate for the interaction between recombinant capability and specific complementarity in is positive and significant ($p < 0.05$) compared to generic complementarity. Hence, our Hypothesis 2 is also supported.

For the second condition, Model 2 presents the relationship between period of uncertainty and product complementarity. In the discrete-time complementary log-log model, a positive coefficient implies a positive relationship with the likelihood of entry or vice versa. In Hypothesis 3, we suggest that specific complementors are more likely to enter the printer market compared to generic ones in stable external environment. It is supported by the result shown in Model 2 ($p < 0.01$). Hence, we claim that Hypothesis 3 is also supported. Model 3 enters recombinant capability and period of uncertainty together with the main independent variable, showing that point estimates for recombinant capability ($p < 0.05$) and period of uncertainty ($p < 0.01$) remain consistent with Models 1-2.

[Insert Table 4 about here]

To tease out the effect of firm size on market entry, we did a two-sample t test using groups of specific complementors and generic complementors. We do not find a statistically significant difference in the means of specific complementors and generic complementors.

DISCUSSION

Contributions and implications

Our findings advance research on complementarity and market entry. Prior studies have increasingly emphasized the role of complementary assets in technological choices and market entry (e. g., Teece, 1986; Tripsas, 1997; Kapoor & Furr, 2015). However, almost no research has investigated the effect of the relatedness stemming from product complementarity on the incentive for complementors to enter a focal market. In this study, we address this gap by developing and testing a new theory regarding the effect of the degree of product complementarity on market entry. Specifically, we investigate how the different types of product complementarity can provide firms with different incentives and capabilities to enter a new market by focusing on two types of complementarities: specific and generic. We argue that firms that originate from a specific complementary market are more likely to enter a focal market than firms from a generic complementary market. Our results also suggest that possessing more recombinant capabilities facilitates new market entry by allowing the firm to utilize the pre-entry capabilities associated with complementarity. Moreover, we found that entrepreneurial start-ups are more likely to enter than diversifiers.

These findings speak directly to several streams of literature on strategy, entrepreneurship, and innovation. First, our findings help scholars to understand better the underlying economics of relationships between producers of complementary goods. Recent studies in strategic management and innovation have discussed the importance of collaborations among complementors (Kapoor & Lee, 2013; Gawer & Henderson, 2007), assuming that these actors have, in principle, aligned incentives. For example, extensive research on ecosystems indicates that firms within an ecosystem carry out interdependent innovation activities as upstream and downstream actors and together contribute to the maximization of the overall value for the end user (Adner, 2017; Adner & Kapoor, 2010; Jacobides et al., 2018; Kapoor, 2018; Ganco, Kapoor, & Lee, 2020). However, there might also be conflicts between the firm in charge of the coordination effort and complementors, which are usually underestimated (Yoffie & Kwak, 2006). These conflicts may lead complementors to pursue competitive strategies toward the focal firm. We add to Casadesus-Masanell and Yoffie's (2007) discussion on cooperation and conflict between complementors by showing that the degree of product complementarity can enlarge potential conflicts and lead to entry into the focal market.

Second, our findings add to the rich body of research on the role of knowledge recombination. According to a recombination theory, firms with higher recombinant capabilities are more capable of integrating knowledge components, each of which is associated with a technological concept. Therefore, recombinant capability can be an essential source of competitive advantage (e. g., Carnabuci & Operti; 2013; Xiao et al., 2021). We engage in this conversation by emphasizing the role of the recombination of relevant knowledge generated from the nature of product complementarity and its potential impact on firms' market entry strategies. Our findings ground several promising pathways for continued research at the intersection of recombinant capabilities and market entry strategy.

Finally, our results contribute to the literature on pre-entry capabilities by revealing a novel antecedent leading to the market entry decisions of firms. This research stream has been primarily concerned with the importance of similarity between the pre-entry resources of established firms in other industries and the required resource profile of the new industry (e. g., Helfat & Lieberman, 2002). For example, Klepper and Simons (2000) analyzed the entry by radio producers to the US television receiver industry and found that potential radio entrants with more experience producing home radios were significantly more likely to enter the television industry. Relatedly, Lane (1988) found that producers of computers and safes were much more likely to enter the automated teller machine (ATM) manufacturing market than other potential entrants, given that they possessed the most relevant pre-entry technological and manufacturing expertise.

In our study, we add one more lens to pre-entry capabilities by focusing on the nature of product complementarity. By so doing, we identify a novel potential source of pre-entry capabilities that create different paths for potential entrants to build a competitive advantage. While potential reasons leading specific complementors to enter the focal market may range from protection against potential misappropriation hazards to misalignment of incentives, our analysis has shown that the degree of product complementarity might also shape the decisions.

Limitations and future research directions

Although our work makes several contributions to the literature, it has several potential limitations. First, although we covered a long time period of industry evolution, our use of the computer printer industry context may potentially limit the generalizability of our findings. In the computer printer industry, fifty percent of the firms entered the market before 1986, and the industry underwent a gradual shake-out after 1992. The changes in terms of competitive dynamics are relatively limited thereafter. Moreover, the findings of this study might be limited to the unavailability of part of the dataset. Given that most of the firms were active during the period between 1970 and 2000, our study suffers from the limitation of data availability.

Besides, our sample of firms might suffer from selection bias since we consider only firms that entered the printer business. We address this issue in two ways, first, by adopting similar strategies from prior studies (Klepper & Sleeper, 2005; Cockburn & MacGarvie, 2011). The estimation strategy exploits the difference across the timing of entry and technological product generations. Second, when examining the entry to new technological product generations, we include incumbent firms doing printer business in the previous technological generation but did not continue their business in the new generations. Nevertheless, a better strategy to solve this issue is to include in our sample a list of firms that are potential entrants by a matching method based on firm characteristics such as pre-entry sectors, the types of business, size, and age.

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Table 1. List of Main Variables and Data Sources

Variables	Information description	Data source
Market entry	0, 1 = if a firm had entered the computer printer market by producing a printer product	SpecCheck, CorpTech, WEMA UsedPrice, PC Mag, Computer World, Info World
Complementor	The entrant's pre-entry products are specific complementary to the printer; generic complementary to the printer; not complementary to the printer.	SpecCheck, CorpTech, WEMA UsedPrice, PC Mag, Computer World, Info World, Compustat
Recombinant Capabilities	A firm's capabilities to understand the linkages among and combine knowledge elements from various knowledge domains	PatentsView, Orbis IP
Period of Uncertainty	0, 1 = if the fiscal years are between 1980 and 1992	SpecCheck, CorpTech, WEMA UsedPrice, PC Mag, Computer World, Info World

Table 2. Descriptive Statistics and Correlations

Variables	Mean	S.D.	Min	Max	1	2	3	4	5	6
1. Entry	.031	.175	0	1	1.000					
2. Specific Complementor	.158	.364	0	1	0.109***	1.000				
3. Recombinant Capability	.013	.07	0	.607	0.057***	-0.064***	1.000			
4. Period of Uncertainty	.198	.399	0	1	0.245***	0.261***	0.141***	1.000		
5. Incumbent	.85	.357	0	1	-0.218***	-0.284***	-0.062***	-0.379***	1.000	
6. Prior Experience	.021	.144	0	1	0.090***	0.066***	0.110***	0.202***	0.062***	1.000
7. Firm Size (ln)	-2.667	1.365	-4.343	4.925	0.069***	-0.001	0.275***	0.427***	-0.092***	0.151***
8. Org Experience	38.805	17.77	0	122	-0.228***	-0.144***	0.109***	-0.325***	0.192***	-0.141***
9. Firm Born Year	2.302	.987	1	4	0.024**	-0.119***	-0.160***	-0.301***	0.156***	-0.092***
10. Japan	.079	.27	0	1	0.014	-0.067***	0.232***	0.157***	-0.038***	-0.004
11. Inkjet	.12	.325	0	1	0.147***	0.197***	0.167***	0.398***	-0.340***	0.205***
12. Industry Clock	25.18	13.52	1	50	-0.073***	-0.203***	-0.120***	-0.524***	0.300***	-0.157***
13. ln_year	2.474	.997	0	3.912	-0.142***	-0.178***	-0.063***	-0.416***	0.299***	-0.135***

Variables	7	8	9	10	11	12	13
7. Firm Size	1.000						
8. Firm Age	0.031***	1.000					
9. Firm Born Year	-0.240***	-0.435***	1.000				
10. Japan	0.098***	0.012	-0.167***	1.000			
11. Inkjet	0.268***	-0.157***	-0.183***	0.131***	1.000		
12. Industry Clock	-0.272***	0.059***	0.399***	-0.123***	-0.311***	1.000	
13. ln_year	-0.158***	0.336***	-0.017*	-0.047***	-0.259***	0.783***	1.000

Notes. Our study is based on 8,582 firm-year observations. *** p<0.01, ** p<0.05, * p<0.1

Table 3. Event History Analysis of Market Entry

VARIABLES	Model 1 Cloglog	Model 2 Cloglog	Model 3 Cloglog
Complementor	0.485**		
	(0.198)		
Specific Complementor		0.581***	0.320**
		(0.214)	(0.151)
Generic Complementor		0.412**	
		(0.209)	
Prior Experience	0.964***	0.975***	1.180***
	(0.244)	(0.245)	(0.253)
Org Experience	-0.103***	-0.102***	-0.0811***
	(0.00846)	(0.00849)	(0.00867)
Inkjet	0.339***	0.337***	0.497***
	(0.130)	(0.130)	(0.146)
Incumbent	-0.911***	-0.891***	-0.969***
	(0.155)	(0.156)	(0.176)
Firm Size	0.0557*	0.0648*	0.0770**
	(0.0329)	(0.0340)	(0.0350)
Japan	0.206	0.223	0.354
	(0.217)	(0.217)	(0.232)
Industry Clock	0.0411***	0.0416***	0.0279**
	(0.0116)	(0.0116)	(0.0129)
lnyear	0.0513	0.0487	0.271**
	(0.108)	(0.108)	(0.125)
Constant	-0.473	-0.484	-1.057***
	(0.314)	(0.315)	(0.276)
Firm Born Year FE	YES	YES	YES
Non-complementors included	YES	YES	NO
N. observations (firm-year)	8,582	8,582	5,587
Log-Likelihood	-854.8	-854.1	-697.1

Notes. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 4. Event History Analysis of Market Entry

VARIABLES	Model 1 Cloglog	Model 2 Cloglog	Model 3 Cloglog
Specific Complementor (SC)	0.316**	0.877***	0.875***
	(0.156)	(0.307)	(0.307)
Recombinant Capability (RC)	0.799		0.484
	(0.801)		(0.853)
SC x RC	4.342**		3.738*
	(1.850)		(1.959)
Period of Uncertainty (PU)		2.614***	2.583***
		(0.369)	(0.369)
SC x PU		-0.683*	-0.699**
		(0.355)	(0.356)
Prior Experience	1.189***	1.139***	1.150***
	(0.254)	(0.252)	(0.254)
Org Experience	-0.0814***	-0.0492***	-0.0496***
	(0.00873)	(0.00830)	(0.00840)
Inkjet	0.511***	0.664***	0.674***
	(0.148)	(0.151)	(0.154)
Incumbent	-0.958***	-1.147***	-1.143***
	(0.179)	(0.175)	(0.179)
Firm Size	0.0660*	0.0269	0.0178
	(0.0367)	(0.0352)	(0.0385)
Japan	0.358	0.362	0.361
	(0.233)	(0.240)	(0.241)
Industry Clock	0.0264**	0.0872***	0.0849***
	(0.0128)	(0.0149)	(0.0149)
lnyear	0.310**	0.101	0.132
	(0.126)	(0.124)	(0.125)
Constant	-1.172***	-4.545***	-4.579***
	(0.282)	(0.537)	(0.537)
Firm Born Year FE	YES	YES	YES
Non-complementors included	NO	NO	NO
N. observations (firm-year)	5,587	5,587	5,587
Log-Likelihood	-692.5	-656.6	-653.6

Notes. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix 1.

Index to the United States Patent Classification (USPC) System regarding core printer-related patents. https://www.uspto.gov/web/patents/classification/uspcindex/indextouspc.htm			
Number	**USPC Class**	**USPC Subclass**	**Descriptions**
1	101		Printing
2	205		Electrolysis: processes, compositions used therein, and methods of preparing the compositions.
3		69	Printing plate or electrotype
4		127	Product is printing member
5		640+	Electrolytic erosion of a workpiece for shape or surface change (e.g., etching, polishing, etc.) (process and electrolyte composition)
6	345		Computer graphics processing and selective visual display systems.
7		418+	Computer graphics processing
8	355		Photocopying
9		18+	Projection printing and copying cameras
10		78+	Contact printing
11	358		Facsimile and static presentation processing.
12		1.9+	Attribute control
13		1.11	Character or font
14		2.99+	Bi-level image reproduction (e.g., character or line reproduction)
15		3.01+	Multi-level image reproduction (e.g., gray level reproduction)
16		3.03+	Error diffusion in gray level or halftone generation
17		3.06+	Halftoning (e.g., a pattern of print elements used to represent a gray level)
18		3.24+	Adaptive image reproduction
19		3.26	Distortion control in image reproduction (e.g., removing, reducing or preventing image artifacts)
20		3.27	Enhancement control in image reproduction (e.g., smoothing or sharpening edges)
21		3.28	Embedding a hidden or unobtrusive code or pattern in a reproduced image (e.g., a watermark)
22	400		Typewriting machines.
23		112+	Annular typewriter (e.g., for typing around circumference of platen)
24		165.1+	Via manually powered actuation other than by key-board (e.g, stylus selection)
25		709	For aligning record-medium with print-point or print-line (e.g., for facilitating correction of error, etc.)
26	493		Manufacturing container or tube from paper; other manufacturing from a sheet of web.
27		187	With printing or photographic reproduction
28		962	Closure (e.g., tie string, valve, etc.)
29	705		Data processing: financial, business practice, management, or cost/price determination.
30		24	Specified transaction journal output feature (e.g., printed receipt, voice output, etc.)

31		60	Postage metering system
32		62	Having printing detail (e.g., verification of mark)
33		408	Specific printing
34		410	Specialized function performed

Appendix 2.

SIC codes in defining specific and generic complementary market		
Number	**SIC Code**	**Descriptions**
1	2752	Commercial Printing, Lithographic
2	2893	Printing Ink
3	3555	Printing Trades Machinery and Equipment
4	3571	Electronic Computers
5	3572	Computer Storage Devices
6	3575	Computer Terminals
7	3577	Computer Peripheral Equipment, Not Elsewhere Classified
8	3578	Calculating and Accounting Machines, except Electronic Computers
9	3579	Office Machines, Not Elsewhere Classified
10	3651	Household Audio and Video Equipment
11	3661	Telephone and Telegraph Apparatus
12	3663	Radio and Television Broadcasting and Communications Equipment
13	3674	Semiconductors and Related Devices
14	3812	Search, Detection, Navigation, Guidance, Aeronautical, and Nautical Systems, Instruments, and Equipment
15	3861	Photographic Equipment and Supplies
16	4812	Radiotelephone Communications
17	7334	Photocopying and Duplicating Services
18	7372	Prepackaged Software
19	7373	Computer Integrated Systems Design

Notes. We include the above SIC codes in our original sectors of printer industry. Specifically, the sectors that are matched from Compustat database where there are more than three firms from our dataset that diversified from: 3571, 3577, 3579, 3651, 3661, 3663, 3674, 7372, 7373. Less than two firms are diversified from the following sectors: 3555, 3572, 3575, 3578, 3812, 3861, 4812, 7334. We also include SIC codes 2752, 2893, 3663, 7334 based on archival data source of the descriptions of industry and products for certain firms.

CHAPTER III. GAINING ADVANTAGES FROM LEGACY: THE ROLE OF PRIOR MARKET EXPERIENCES IN INCUMBENTS' ADAPTATION TO TECHNOLOGICAL DISCONTINUITIES

ABSTRACT

While scholarly discussions on technological discontinuities have primarily focused on the supply-side of radical technological changes, they can also cause demand-side market disruptions. Specifically, the characteristic of customers might change radically in a new technological generation due to their preference shifts and sometimes the emergence of a new set of customers. As such, I investigate the relationship between incumbent firms' prior market experiences and their adaptation to technological discontinuities. I empirically test our hypotheses using longitudinal data of market entry and exit among multiple technological generations in the computer printer industry between 1951 and 2021. Our results suggest that the prior market experiences related to the new set of customers could be a source of incumbent heterogeneity in successfully continuing its business in new technological generations.

Keywords:

Technological discontinuities; market experiences; incumbent heterogeneity; adaptation

INTRODUCTION

Innovation and management scholars have long proposed that technological discontinuities present opportunities and challenges for incumbent firms. Possessing necessary capabilities helps firms to adapt to the changes successfully, while firms without such capabilities will suffer. Indeed, the literature on technological discontinuities is rich on how the incumbents' legacy in the old technology may provide the foundation of knowledge and absorptive capacity which are needed for new technologies (Cohen & Levinthal, 1990), even though it can be a source of inertia to adapt to new technologies (Gilbert, 2005). Yet, technological discontinuities may also reshuffle the market. In other words, technological discontinuities lead to changes in not only supply-side factors but also demand-side conditions (e.g., Adner & Snow, 2010). In this paper, I consider the implications of incumbents' market-related capabilities in adapting to technological discontinuities. I argue that recognizing the demand-side changes influenced by their market legacy is crucial in understanding the heterogeneity of incumbents' successful adaptation to technological discontinuities.

A growing body of literature highlights the importance of demand heterogeneity due to preference shifts and new customer segments for technological discontinuities. For instance, interactions between technological improvements and the heterogeneous preferences of different customer segments can influence industry evolution with the existence of new technologies (e.g., Christensen & Bower, 1996; Adner & Snow, 2010; Ye, Priem, & Alshwer, 2012). Relatedly, the literature on firms' pre-entry experience also emphasizes the importance of capabilities and resources within organizations and industries in determining a firm's market entry and survival in that the more similar pre-entry capabilities and the required resources in an industry are, the higher likelihood that a firm has in entering and surviving in that industry (e.g., Helfat, & Lieberman, 2002; Adams, Fontana, & Malerba, 2016; Fontana, Malerba, & Marinoni, 2016). In other words, even though a technological discontinuity may hamper some crucial parts of incumbents' technology-related competencies, firms may still benefit from their customer-related capabilities in the new market after discontinuities.

This study explores how firms with post-discontinuity market-related experiences can better adapt to technological discontinuities. More specifically, I focus on whether market-related experiences may help them enter and survive in the markets with technological discontinuities. Our theoretical considerations suggest that market legacy helps incumbents better identify the needs of the new set of customers. Firms with market-related experiences can do ongoing experimentation to identify customer needs in the new application areas, which is essential in successfully providing attractive products (Danneels & Sethi, 2011). Additionally, as market-related capabilities further facilitate coordination with the upstream and downstream environment (Aggarwal & Wu, 2015), market-side experiences are more likely to generate and maintain customer trust, both of which are necessary for successful market entry. Lastly, I also suggest that incumbents with market-related experiences will be more likely to manufacture products that can adopt multiple new technologies. As firms with market-related experience can get timely feedback on customers' preferences, reducing uncertainty from the demand-side, these firms are relatively more prone to invest in competing technologies.

I test these arguments by analyzing a unique longitudinal dataset on product market entry and exit in the computer printer industry between 1951 and 2021. This setting is particularly suitable for our study because we can observe three distinctive technological generations in the printer industry during its life cycle. Specifically, I examine the incumbent dot-matrix printer manufacturers' likelihood of entry to the subsequent technological generations (i.e., inkjet, laser, or combinatively as nonimpact printers). While dot-matrix printers were mainly for mainframe computers that are industrial and commercial uses, inkjet and laser printers were primarily targeted at personal computers and thus the mass market, especially when these printers became popular in the mid-1980s. Thus, dot-matrix incumbents are not homogeneous because some of these firms have previous experience with B2C businesses while others do not. As such, those dot-matrix incumbent firms with prior experiences in B2C businesses even before entering the printer market (i.e., firms that diversified to dot-matrix printers with B2C experiences before) may benefit from their market-related experiences, which are crucial in the post-discontinuity market, and thus have relative advantages in entering the printer markets of next generations over dot-matrix incumbents that only had industrial market experiences (e.g., by doing B2B businesses). Our results from discrete-time event-history analyses and ordinary least square regressions in which I control for potential endogeneity support our hypotheses.

This study makes three primary contributions. First, I contribute to the technological discontinuity literature (Hill & Rothaermel, 2003; Eggers, 2018; McKinley, 2022) and focus on the underexplored link between the incumbent's market legacy and entering and surviving in new technology generations when there is new market emergence. In this study, I address this gap by developing a new theory regarding the advantages incumbents can gain from their history by explicitly investigating the role of the prior market experiences of incumbents that share the same customers with the new technology product market in facilitating incumbents' market continuation. Second, our study contributes to the studies of the pre-entry experience of the firm (e.g., Helfat & Lieberman, 2002; Fontana, Malerba & Marinoni, 2016), which emphasizes the role of the capabilities and resources within organizations and within industries from their historical antecedents in entering different but related industries. I suggest that incumbents can redeploy pre-entry market capabilities to the new market when it shows similar characteristics because resource similarity can affect the likelihood of entry, adaptation, and survival. Third, whereas substantial literature considers the importance of a firm's pre-entry resources and capabilities to be eroding over time in dynamic environments (Bayus & Agarwal, 2007), I investigate the likelihood of incumbents to continue their business in the new technology generations by considering their resources endowments even long before the technological changes. I suggest that incumbents' relative entry and survival advantage is greater for firms with market knowledge storage all through their industry life cycle.

The remainder of the paper is organized as follows. Section 2 develops our theoretical framework and arguments and formulates testable hypotheses. Section 3 provides an overview of the empirical setting, followed by explanations of the data collection and empirical methods. Then session 4, I present the results of the empirical analysis. In Section 6, I discuss our findings and primary contributions, and I end by raising the study's potential limitations.

THEORY DEVELOPMENT

Technological discontinuities

Management studies suggest that technological discontinuities can be either competence-enhancing or competence-destroying (Tushman & Anderson, 1986). When technological discontinuities are competence-enhancing, incumbents can maintain their competitive advantage over new entrants by retaining their valuable capabilities (Klepper, 1996, 2002; Peltoniemi, 2011 for a review). However, when technological discontinuities are competence-destroying, incumbents may have to search for alternative capabilities not present within their value chain as their existing capabilities have become obsolete (Nelson & Winter, 1977; Anderson & Tushman, 1990). As these technological discontinuities are often radical in nature, such as with products that draw upon fundamentally different science and technologies (Tripsas, 2008), they often lead to alterations of the established demand and supply conditions (Sosa, 2011; Eggers & Park, 2018). Therefore, instead of enabling substantial improvements in the relevance of incumbents' existing knowledge and skills, as in competence-enhancing technological discontinuities, incumbents that encounter competence-destroying technological discontinuities may lose their competitive advantages and thus need to start from scratch to maintain their level of performance. In this paper, I conceptualize firm adaptation to technological discontinuities as an outcome instead of efforts to achieve the outcome (Wang, Aggarwal, & Wu, 2020). Given that providing new products that adopt new technologies is crucial for a firm's strategic positions related to its environment and influences its competitiveness and viability (Danneels & Sethi, 2011), I treat market entry (Moeen, 2017; Nerkar & Roberts, 2004) in the new technological generation through new product development and innovation as an essential aspect of successful adaptation to external changes. Heterogeneous incumbent firms can successfully adapt to competence-destroying technological discontinuities

Heterogeneous market entry

Given the heterogeneous implications of technological discontinuities in terms of competence requirements in the industry for incumbents' competitive advantages, it is worth exploring whether incumbent firms can successfully adapt to competence-destroying technological discontinuities. In addition, understanding why some incumbents can be relatively more successful in their adaptations is crucial in investigating the incumbent heterogeneity in adapting to radical technological discontinuities (Eggers & Park, 2018). Although there exist prior studies showing evidence of why firms face difficulties with the existence of radical technological changes (e.g., King & Tucci, 2002; Eggers & Kaplan, 2009; Rothaermel & Hill, 2005), we still observe incumbents that can adapt to and thrive across competence-destroying technological discontinuities and successfully maintain the market leadership in the new technology generations.

One critical source of this heterogeneity may hinge on demand-side conditions of the technological discontinuities. Although much of the attention in the strategy literature has paid emphasis on the supply-side factors, a growing body of literature highlights the importance of demand heterogeneity for technological discontinuities (e.g., Christensen & Bower, 1996;

Adner & Snow, 2010; Ye, Priem, & Alshwer, 2012). In particular, interactions between the distinctive technologies and the heterogeneous preferences of different customer segments can be critical in industry evolution. On the one hand, the emergence of new technologies can attract and create a new customer segment in the market. Oftentimes, technological discontinuities are associated with not only an increase in customer size but also a fundamental change in customer preferences and needs (Tripsas, 2008). For instance, as a user industry, the growth of the insurance industry significantly increased the complexity of information processing requirements of the tabulating industry, leading to the emergence of new technology (Yates, 1993). Similarly, the evolution of customers may also increase the complexity of the customer base because technological discontinuities can create new submarkets that are composed of a heterogeneous customer base even within the same industry (Buenstorf, Guenther, & Wilfling, 2022). For instance, while the successive generations of disk drive technologies were not favored by the existing customers who emphasized the storage capacity, other new customers were attracted by these new technologies that had a better fit in terms of convenience (Christensen & Bower, 1996). This is a typical case where the new customer base becomes more relevant to the firms' success by generating a new "dominant submarket." While it has received less attention in the extant literature, submarkets are the crucial venue in which a distinct set of customers eventually became more critical for technological discontinuities in the industry.

On the other hand, identifying the needs of a new set of customers is essential in successfully providing attractive products with the emergence of new technologies. Arguably, adaptation to the emergence of the dominant submarket is eventually a matter of the firm's resources. For instance, as a successful adaptation to demand-side change requires an alignment between firms and the demand-side environments (Wang, Aggarwal, & Wu, 2020), firms can accumulate customer-related capabilities through prior repeated customer interactions (Holloway & Parmigiani, 2016; Mawdsley & Somaya, 2018). In our context of dominant submarket emergence, the potential pathways for the firm to access customer capabilities can also arise from their pre-shock relationships and market experiences (Ethiraj, Kale, Krishnan, & Singh, 2005). When a new market is beyond an incumbent firm's existing base of market knowledge, it may further suffer from a lack of timely information on the demand conditions (Wang, Aggarwal, & Wu, 2020), which will reduce the likelihood of catering to customers' needs in the new submarket.

Moreover, a firm may also find it hard to do ongoing experimentation to identify customer needs in the new application areas (Danneels & Sethi, 2011), especially when it is embedded in a well-established customer relationship which inhibits a firm's motivation and capability to perform trial-and-error experiments in other customer contexts (Li, Madhok, Plaschka, & Verma, 2006). As such, whereas firms that do not possess enough experience with the demand conditions may encounter various potential problems, firms with a broader set of customer bases can gain substantial insights into new areas of demand, which would then aid in identifying application-specific requirements. Relatedly, prior market-related experiences can facilitate an establishment of trust with customers as well as other actors in the ecosystem (Aggarwal & Wu, 2015; Connelly, Crook, Combs, Ketchen, & Aguinis, 2018). Thus, relevant market experience by an incumbent firm would lead to a higher likelihood of market entry by the focal firm compared to firms without experience in relevant market conditions in their previous businesses. Therefore,

> *Hypothesis 1. When technological discontinuities create a new market, incumbents' previous experience in markets that share similar characteristics (such as customer-orientation) increases the likelihood of the market entry.*

Multiple markets entry and resource redeployment

So far, the discussion has implicitly assumed that technological discontinuities generate a new market. However, technological discontinuities can create *multiple markets* that coexist for some time. As firms often have multiple technology options in an era full of competing for technological choices (Kretschmer, 2008), understanding how the relationship between previous market experience and market entry likelihood can apply to situations in which technological discontinuities generate multiple new markets.

There exist several reasons why firms with previous experiences in markets that share some similar characteristics with newly generated markets due to technological discontinuities are more likely to be active in these multiple markets. First, firms may be more likely to succeed in a technology that requires understanding potential customer bases. These firms face a reduced level of uncertainty from the market side because familiarity with a customer base provides an environment for incumbents to gain timely information on customer preferences. These insights can be applied quickly to products based on another new technology. Relatedly another benefit of having prior experiences in the market after technological discontinuities is related to the possibility of experimenting with their products by doing trial-and-error. Firms can utilize experiments to gather timely feedback from customers about the preferences of the products (Li et al., 2006). Thus, firms with previous experiences in similar markets based on customers will be less concerned with entering new markets that are also customer-based because they have lower risks yet more opportunities for experimenting with their resources to increase the possibility of more effective utilization.

Second, the flexibility that these firms possess may provide an essential condition to address changing customer preferences. Firms that have market experience and thus legacy within the market may be better positioned to adapt to technological discontinuities and more likely to be flexible in the building and deployment of resources and competencies under different technology generations (Buganza & Verganti 2006). With a higher level of flexibility, the possibility for firms to do more exploration by developing and launching distinctive new products increases (Levinthal & March, 1993; Danneels & Sethi, 2011). When faced with competing technologies, flexible firms are more likely to explore a wide range of options when developing new technologies and products that are needed to pursue new opportunities or to avoid disadvantages from the competition (Eisenhardt & Martin, 2000). In contrast, a firm that entered a market where they are less familiar with the customers will have to start to learn about the customers from scratch and are more likely to focus on ways to build up the resources and capabilities that are needed to address the changing customer needs (Danneels, 2002). Thus, it will be more likely to adopt a resource-focused approach and do more exploitation in one technology domain and improve product quality in a customer environment that they are less familiar with but less able to assemble the resources required for explorative products.

Third, application-specific competencies can be applied across technology generations as long as they serve the same market and provide a favorable condition for market entry by these firms. An incumbent's R&D competencies can be application-specific if they are tied to the knowledge of a specific market. One example of application-specific R&D competencies is that oncology research is only helpful in developing and improving anti-cancer drugs. Similarly, the research on the automotive engine, which is about the knowledge of lean combustion in hydrogen-enriched environments and drivability is also application-specific in that it applies to the automobile market only (Sosa, 2009). Because these capabilities are market specific, they remain undisrupted even when the technologies change as long as the market remains unchanged (Sosa, 2009). Firms already existing in one technology market can redeploy these capabilities to another technology that serves the same market (Lieberman, Lee, & Folta, 2017). Hence, when multiple technologies serve the same market, application-specific capabilities have accrued to firms that are producing products using one technology and can be a source of competitive advantage for them. Hence, they are more likely to take advantage of exploring multiple new technologies in the same market after technological discontinuity. In sum, I argue that dot-matrix incumbents with prior B2C experiences will tend to have a longer overlap in terms of years between inkjet printers and laser printers than dot-matrix incumbents without B2C experiences. Thus:

> *Hypothesis 2. When technological discontinuities create multiple new markets, incumbents' previous experience in markets that share similar characteristics (such as customer-orientation) increases the likelihood of the multiple market entries*.

METHODS

History background of the industry

To investigate the research issue, I apply our theoretical model to the computer printer industry between 1951 and 2021 by including three distinctive technological generations during its industry life cycle. When the computer printer industry first emerged in the 1950s, the dot-matrix printer was the representative product of impact printers. IBM developed and marketed the first dot-matrix printer in 1957. Throughout the 1970s and 1980s, dot-matrix printers were generally considered the best combination of expense and versatility. They became the most typical form of printers used with personal and home computers in computer networks in the 1990s. However, impact print technology had poor print quality and was extremely noisy and costly. In the mid-70, mainframe computing was starting to fade, and the minicomputer market was exploding. However, there was nothing comparable for the minicomputer market.

Impact print technology had poor print quality and was extremely noisy and costly. IBM and Xerox had introduced laser xerographic printers that cost $500,000 or more for mainframe computers. In the 1980s, with the advent of personal computers stimulating a large market for desktop printers, non-impact printers gradually took over the market. Inkjet printers were one of the representative products of non-impact printers. Thermal Ink-jet print head technology was invented in the 1970s and, a decade later, would dominate the industry. The first inkjet printer was developed by Hewlett-Packard (HP) in 1976. In the late 1970s, inkjet printers that could reproduce computer-generated digital images were developed mainly by Epson, HP, and Canon. However, inkjet printers did not gain popularity until the mid-1980s. In the late 1980s and early 1990s, inkjet printers disrupted the dominant design, dot-matrix printing. HP developed the HP DeskJet inkjet printer in 1988, which is considered the first mass-marketed inkjet printer. By the dawn of the 1990s, inkjet printers became more common than PC printers. Inkjet printers ranged from small, inexpensive consumer models to expensive professional machines, but they were not the only alternative to dot-matrix. In the mid-1970s, the minicomputer market was exploding. IBM and Xerox had introduced xerographic laser printers for mainframe computers, but nothing was comparable for the minicomputer market. HP seized the opportunity, and in 1984, they launched the first desktop laser printer, HP LaserJet 8ppm, for the retail market. It was the first laser printer for the mass market after personal computers became more widespread. Other models and laser printer manufacturers, such as Brother Industries or IBM, quickly followed the HP LaserJet printer.

Data and sample

Our analysis is based on a unique dataset encompassing the population of computer printer producers active in the three technological generations (dot-matrix printers, inkjet printers, and laser printers). The dataset was compiled from multiple sources, including SpecCheck (de Figueiredo & Silverman, 2007), CorpTech, and the WEMA (Western Electronics Manufacturing Association) Database. It lists information on the firms' name, entry year, generations of products, firm incorporation year, printer market exit, previous industry, and the firms' products. I complemented these data by manually collecting data from multiple archival data sources, including *UsedPrice*, *PC Mag*, *Computer World*, and *Info World*, to deal with the missing observations. I also matched some firms with Compustat Database to double-check and get new corporate information, such as the number of employees, countries, sales, and R&D expenses. Our final dataset consists of 253 firms doing business in the computer printer industry (either dot-matrix printers, inkjet printers, or laser printers) from 1951 till 2021.

Dependent variables

In our first hypothesis, I capture the likelihood of an incumbent firm in the dot-matrix printer market entering the next technological generation (nonimpact printer) in our first hypothesis. I examine the entry decision of a dot-matrix incumbent in a new technological generation using the discrete-time duration model. A dot-matrix incumbent *i* becomes 'at risk' of entering the inkjet market *m* at a specific time period *t* which starts from the first year of commercialization of inkjet printer or laser printer. Entry occurs in the year in which a firm produces an inkjet printer or laser printer. The observed events in year *t* are coded as 1 ($ENTRY_{it} = 1$), whereas those not observed by the end of year *t* are coded as 0 ($ENTRY_{it} = 0$). I consider multiple entry modes such as in-house development, an alliance, or an acquisition. I adjust the entry mode by treating a firm formed by the combination of two existing firms as a new entry. Any market in which either predecessor firm operated is removed from the new firm's risk set.

The second hypothesis is intended to capture how active a firm is in multiple technology generations. Therefore, I construct our dependent variable as *Overlap,* which equals the number of overlapping years a firm stays in inkjet printers and laser printers. To accommodate the nature of the dependent variable, I specified ordinary least square regression models for our analyses.

Explanatory variable

The explanatory variable is Business-to-Customer (B2C) experience. This is a categorical variable equal to one if a dot-matrix incumbent has B2C experiences before, zero if they only have experiences in Business-to-Business (B2B) experience. Specifically, I classify firms based on the types of customers they are serving by looking into the text description of the firm's history about their industries and products. An example of B2B firms' description is "…hobbyists for supplying electronic kits containing everything one needed to construct stereo, electronic testing, or amateur radio equipment. Some of their equipment was of professional standards, and many scientists and engineers would routinely purchase kits for laboratory use".

[Insert Table 1 about here]

Control variables

Firm age is computed as the difference between market entry and the firm's founding year. It captures the effect of prior organizational experience at the time of entry. *Organizational experience* is measured as the logarithm of the number of years difference between the starting year of the specific technology generation (if a firm was established before the generation starting year) or a firm's establishment year (if a firm was established after the generation starting year) and the year of that technological product market entry. A firm's corporate status might also affect the likelihood of market entry. To capture a firm's market position, I created a dummy variable, *Public firms,* that equals one if the firm is a public firm at the time of entry and zero if not. The nature of the products in a firm's history might also influence entry. *Specific complementor*, a categorical variable equal to one if a firm was producing specific complements to a printer in its industry history, zero if not. I treat firms that produce ink or toner cartridges, paper, and computers as specific complementors.

RESULTS

Descriptive statistics

I recorded the annual market entries of all the computer printer firms from 1957 until 2021. Tables 2- 4 show the means, standard deviations, and correlations for all variables.

[Insert Tables 2-4 about here]

Although many pairwise correlations in Table 2a-4a are significant, there are no critically collinear variables. In fact, for the sample consisting of nonimpact printers, the highest variance inflation factor (VIF) across our models is 4.58 and the mean VIF is 2.25, below the recommended critical level of 10, above which multicollinearity is perceived to be a problem (Neter et al., 1996). Similarly, for the sample of inkjet printers, the highest VIF across our models is 5.28, and the mean VIF is 2.43, also below the recommended critical level of 10. As for laser printers, the highest and mean values of VIF are both below the recommended critical level of 10, with values of 4.3 and 2.13, respectively. To improve reliability in the model estimation, I estimated the models by adding the covariates in sequence one at a time and inspected them for any instability in the coefficients or standard error. I observed no significant changes in the estimates across specifications, confirming that multicollinearity is not an issue.

Main results

To test the effect of prior market experiences on the likelihood of new technological generation entry, I employed event-history analysis based on a sample that consists of only the realized entrant firms. Consistent with recent research, I relied on discrete-time event-history analysis (King & Tucci, 2002; Dowell & Killaly, 2009). The event of interest is whether a firm starts producing nonimpact printers. I begin the analysis by treating all the printer firms in our sample that exist and have not previously entered the new generation as potential entrants (i.e., ‘at risk’ of entering) and ‘drop’ them from the pool of firms at risk once they have entered the new generation. This methodology allows us to consider the firm observation of the risk of event occurrence in a given year as long as the firm is still alive and has not yet entered the market. The probability that firm *i* entered a market *m* in year *t* is thus defined as:

$$Prob[ENTRY_{imt} = 1] = \Pr[T_i = t \mid T_i \geq t, X_{it}] \quad (2),$$ [13]

I present the results of event history analysis (discrete-time logistic model), which shows the probability of new generation entry of the potential entrants in Table 5. In this analysis, I consider entry ‘tout-court’ without distinguishing between the inkjet printer market and the laser printer market.

[Insert Table 5 about here]

Model 1 shows the model that includes only the controls. Model 2 shows the baseline model with the direct effect of dot-matrix incumbents’ prior B2C experience on entry into the nonimpact printer market. Our Hypothesis 1 claims that incumbent firms with previous experience with a particular market (such as B2C) will be more likely to enter the new technological generations that share a common set of customers (that is, B2C) during technological discontinuities. The multivariate estimation results confirm that compared to incumbent firms that only have B2B experiences, firms that are also endowed with B2C experiences from their history are more likely to enter the nonimpact printer market as a successful adaptation to technological discontinuities ($p < 0.001$). Similarly, Models 5 and 8 in Table 5 consider different samples by treating inkjet printers and laser printers as distinct new technological generations compared to dot-matrix printers. Our results show similar findings in the sample where I only looked at nonimpact printers. Thus, I found support for

[13] Note that T_{it} is the discrete random variable about the time of entry while X_{it} is the vector of explanatory variables.

Hypothesis 1.

Furthermore, I did subsample analyses by only examining entry actives after a popular year of the technology generation (i.e., 1987) with the thriving of personal computer developments. Model 6 in Table 5 indicates that firms that had prior B2C experiences are more likely to enter the inkjet printer market compared to those incumbents who did not ($p < 0.01$). Although the results are not significant for the samples of nonimpact printers and laser printers shown in Models 3 and 9, I believe this provides further support for our argument in Hypothesis 1 that incumbents with relevant market experiences are more willing to enter the next generation when the nature of the market became clearer.

In Table 6, Model 1 shows the model that includes only the controls. Model 2 shows the effect of incumbents' B2C experiences on the overlapping years of inkjet printers and laser printers. I suggest in our second hypothesis that superior market capabilities will reduce the uncertainty from the market side, and firms will be more willing to explore multiple technologies to address customer requirements. In line with this hypothesis, the coefficient estimate for the direct effect of B2C experiences in Model 2 is positive and significant ($p < 0.01$), providing support for our Hypothesis 2.

[Insert Table 6 about here]

Additional analyses and discussions

In the above analyses, I treat market entry into new technological generations as one way of incumbent firms' successful adaptation. However, market survival is another crucial consideration of firms (e.g., Adams, Fontana, & Malerba, 2016). Therefore, I also investigate the survival likelihood of the incumbent firms in the new technological generations. I employ two different methods to capture this effect. First, I did ordinary least square regressions in which I constructed our dependent variable *Length of stay*, which equals the number of years an incumbent firm was active in new technological generations. Then, similar to the first hypothesis, I also performed survival analysis using discrete-time event history analysis, and therefore, our dependent variable is the *Exit likelihood.* To be more specific, the less likely a firm is to exit from the market, the higher the likelihood of survival for that firm in that particular market.

I predict that the previous experience with a particular market of an incumbent company increases the likelihood of survival in the new market that shares a common set of customers. To test this argument, I first adopt ordinary least square regression models and examine the relationship between B2C experience and the length of staying years in each generation separately. Our hypothesis is supported by the results in Models 1, 2, and 3 in Table 7 ($p < 0.01$ and $p < 0.001$). Additionally, I show the results in Table 8 by using complementary log-log models of event-history analysis. This allows us to examine the exit likelihood of a firm compared to the other firms in the nonimpact printer, inkjet printer, and laser printer market, respectively. The results in Models 2, 4, and 6 show us that compared to dot-matrix incumbents that only have B2B experiences, those that also have B2C experiences will be less likely to exit from the next technological generations. These findings further provide support our argument that incumbents that have previous experience in markets that share similar characteristics (such as customer-orientation) have a higher likelihood of survival in the new market created during technological discontinuities than those who do not have similar market experiences.

[Insert Tables 7-8 about here]

I did further analyses to examine whether it is likely for firms to leapfrog during multiple technological generations in the computer printer market. Specifically, dot-matrix printers are the first technological generation in the industry, followed by inkjet printers and laser printers. Even though printers based on inkjet technology and laser technology were introduced during the same period, the laser printers were more advanced and lasted longer. Thus, I treat inkjet printers as a prior generation of laser printers. I found that dot-matrix incumbents that entered the inkjet printer market are more likely to enter the laser printer market and stay longer compared to those that did not enter the inkjet printer market. The results are shown in Table 9. These findings suggest that it is difficult for incumbent firms to bypass the stages of development of technological generations by jumping directly to advanced technologies.

[Insert Table 9 about here]

DISCUSSION

The results of our study advance research on technological discontinuities. Prior research identified multiple antecedents of incumbent heterogeneity in terms of surviving or even thriving over technological discontinuities (e.g., Chesbrough, 2015; Eggers, 2018). Studies have increasingly emphasized the differential ability of incumbents to adapt to external changes induced by technological discontinuities (Hill & Rothaermel, 2003; McKinley, 2022). However, almost no research investigated the impact of the incumbent's market legacy in entering and surviving in new technology generations when there is new market emergence. In this study, I address this gap by developing a new theory regarding the advantages incumbents can gain from their history. Specifically, I investigate the role of the prior market experiences of incumbents that share the same set of customers with the new technology product market in facilitating incumbents' market continuation. Given the similarity between the set of customers in incumbent history and the new market after technology discontinuity, I argue and find that incumbents' previous experiences increase the likelihood of entry to the new market that shares a common set of customers when the market is characterized by technological discontinuities. Our findings point to the need to consider market legacy more systematically as an essential factor that can affect incumbent firms' market entry decisions in which their previous market experiences in the new technology market can provide a competitive advantage.

For the literature on pre-entry experience, our study reveals a novel factor of incumbent's market experiences. This research stream has been primarily concerned with the role of the capabilities and resources within organizations and within industries from their historical antecedents in entering different but related industries, which is why the similarity between resources that are needed in different industries is a crucial factoring of the likelihood that a firm will enter a particular industry (e.g., Helfat & Lieberman, 2002; Fontana, Malerba & Marinoni, 2016). Using the capability endowment lens, I shift focus from entering a different industry to continuing business after technological discontinuities and suggest pre-entry market capabilities can be redeployed by incumbents to the new market when it shows similar characteristics. In addition, the results supporting our hypotheses suggest the resource similarity affects the likelihood of entry and survival and the way to adapt.

Our findings also inform research on the endowment of a firm's resources and capabilities. Existing studies have emphasized the importance of the pre-entry experience of a firm as a source of firm heterogeneity because the effects of founding conditions that imprint on an organization can last long (Gort & Klepper, 1982; Agarwal et al. 2002; Helfat & Lieberman, 2002). I add to this stream of research by showing how the market-specific stock of knowledge of incumbents can enable them to leverage collateral assets (Tripsas 2008) that help deal with customer needs in the emerging market after the technological discontinuity. Relatedly, whereas substantial literature considers the importance of a firm's pre-entry resources and capabilities to be eroding over time in dynamic environments (Bayus & Agarwal, 2007), I investigate the likelihood of incumbents to continue their business in the new technology generations by considering their resources endowments even long before the technological changes. I suggest the stock of knowledge can be leveraged by incumbents when it is valid, even in the long run. In other words, the relative entry and survival advantage of incumbents is more significant for firms that have the market knowledge storage all throughout their industry life cycle. We, therefore, complement prior research on pre-entry experience in technological discontinuity, which has received little attention in the otherwise rich market entry literature.

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Table 1. List of Main Variables and Data Sources

Variables	Information description	Data source
Entry Likelihood	0, 1 = if a firm had entered a new technological generation(s) in the computer printer industry by providing products	SpecCheck, CorpTech, WEMA UsedPrice, PC Mag, Computer World, Info World, Compustata
Overlap	the number of overlapping years a firm stays in inkjet printers and laser printers	
Survival Likelihood	the number of years an incumbent firm were active in new technological generations. 0, 1 = if a firm had exited from a new technological generation(s) in the computer printer industry	
B2B experiences	0, 1 = if an incumbent has Business-to-Customer (B2C) experiences before entry new technological generations	

Table 2. Descriptive Statistics and Correlations. Sample for Nonimpact Printer (Combined Inkjet and Laser)

Table 2a. Pairwise Correlations. Sample for Nonimpact Printer (Combined Inkjet and Laser)

Variables	nonimpact	dot-matrix	Prior B2B Experience	Prior B2C Experience	Entry after 1987	Org Experience	Firm Age When Entry	Public Firms	Market Entry Year	Specific Complementor
nonimpact	1.000									
dot-matrix	-0.609***	1.000								
prior B2B experience	-0.393***	0.562***	1.000							
prior B2C experience	-0.144***	0.285***	-0.343***	1.000						
Entry after 1987	0.775***	-0.574***	-0.350***	-0.190***	1.000					
Org Experience	-0.512***	0.282***	0.204***	0.064***	-0.377***	1.000				
Firm Age When Entry	-0.177***	0.038**	0.065***	0.037**	-0.128***	0.236***	1.000			
Public Firms	0.317***	-0.101***	-0.013	-0.070***	0.264***	-0.158***	0.105***	1.000		
Market Entry Year	-0.944***	0.494***	0.323***	0.120***	-0.705***	0.540***	0.195***	-0.303***	1.000	
Specific Complementor	-0.206***	0.221***	0.335***	0.220***	-0.225***	0.176***	0.090***	0.011	0.231***	1.000

**** p<0.01, ** p<0.05, * p<0.1*

Table 2b. Descriptive Statistics. Sample for Nonimpact Printer (Combined Inkjet and Laser)

Variable	Obs	Mean	Std. Dev.	Min	Max
nonimpact	3,844	.487	.5	0	1
dot-matrix	3,844	.74	.439	0	1
prior B2B experience	3,844	.473	.499	0	1
prior B2C experience	3,844	.187	.39	0	1
Entry after 1987	3,844	.411	.492	0	1
Org Experience	3,844	2.376	1.024	0	3.912
Firm Age When Entry	3,844	37.118	20.725	0	122
Public Firms	3,844	.087	.282	0	1
Market Entry Year	3,844	2005.627	15.711	1971	2021
Specific Complementor	3,844	.681	.466	0	1

Table 3. Descriptive Statistics and Correlations. Sample for Inkjet Printer

Table 3a. Pairwise Correlations. Sample for Inkjet Printer

Variables	inkjet	laser	dot-matrix	Prior B2B Experience	Prior B2C Experience	Entry after 1987	Org Experience	Firm Age When Entry	Public Firms	Market Entry Year	Specific Complementor
inkjet	1.000										
laser	0.133***	1.000									
dot-matrix	-0.067***	-0.420***	1.000								
prior B2B experience	-0.072***	-0.332***	0.613***	1.000							
prior B2C experience	0.007	-0.115***	0.349***	-0.218***	1.000						
Entry after 1987	0.632***	0.263***	-0.125***	-0.120***	-0.035***	1.000					
Org Experience	-0.271***	-0.118***	0.058***	0.064***	-0.007	-0.307***	1.000				
Firm Age When Entry	-0.112***	0.146***	-0.072***	-0.017	0.016	-0.201***	0.169***	1.000			
Public Firms	0.119***	0.223***	-0.038***	0.008	-0.044***	0.048***	-0.043***	0.224***	1.000		
Market Entry Year	-0.705***	-0.260***	0.037***	0.058***	-0.037***	-0.864***	0.377***	0.214***	-0.092***	1.000	
Specific Complementor	-0.053***	-0.210***	0.231***	0.335***	0.224***	-0.108***	0.092***	0.076***	0.092***	0.104***	1.000

*** p<0.01, ** p<0.05, * p<0.1

Table 3b. Descriptive Statistics. Sample for Inkjet Printer

Variable	Obs	Mean	Std. Dev.	Min	Max
inkjet	6,313	.186	.389	0	1
laser	6,313	.647	.478	0	1
dot-matrix	6,313	.61	.488	0	1
prior B2B experience	6,313	.37	.483	0	1
prior B2C experience	6,313	.16	.366	0	1
Entry after 1987	6,313	.317	.465	0	1
Org Experience	6,313	2.65	.943	0	3.912
Firm Age When Entry	6,313	44.303	24.394	0	154
Public Firms	6,313	.12	.325	0	1
Market Entry Year	6,313	2013.769	11.367	1971	2021
Specific Complementor	6,313	.623	.485	0	1

Table 4. Descriptive Statistics and Correlations. Sample for Laser Printer

Table 4a. Pairwise Correlations. Sample for Laser Printer

Variables	inkjet	laser	dot-matrix	Prior B2B Experience	Prior B2C Experience	Entry after 1987	Org Experience	Firm Age When Entry	Public Firms	Market Entry Year	Specific Complementor
laser	1.000										
inkjet	0.193***	1.000									
dot-matrix	-0.278***	-0.420***	1.000								
prior B2B experience	-0.207***	-0.299***	0.592***	1.000							
prior B2C experience	-0.065***	-0.091***	0.314***	-0.302***	1.000						
Entry after 1987	0.708***	0.208***	-0.326***	-0.227***	-0.117***	1.000					
Org Experience	-0.501***	-0.123***	0.167***	0.141***	0.037**	-0.383***	1.000				
Firm Age When Entry	-0.127***	0.068***	-0.062***	0.005	0.003	-0.124***	0.211***	1.000			
Public Firms	0.245***	0.256***	-0.107***	-0.027*	-0.058***	0.161***	-0.115***	0.185***	1.000		
Market Entry Year	-0.958***	-0.203***	0.254***	0.193***	0.057***	-0.715***	0.527***	0.175***	-0.225***	1.000	
Specific Complementor	-0.164***	-0.115***	0.232***	0.326***	0.227***	-0.170***	0.144***	0.036**	-0.003	0.167***	1.000

**** p<0.01, ** p<0.05, * p<0.1*

Table 4b. Descriptive Statistics. Sample for Laser Printer

Variable	Obs	Mean	Std. Dev.	Min	Max
laser	4177	.397	.489	0	1
inkjet	4177	.288	.453	0	1
dot-matrix	4177	.689	.463	0	1
prior B2B experience	4177	.437	.496	0	1
prior B2C experience	4177	.179	.384	0	1
Entry after 1987	4177	.352	.478	0	1
Org Experience	4177	2.434	1.015	0	3.912
Firm Age When Entry	4177	38.621	21.685	0	122
Public Firms	4177	.096	.294	0	1
Market Entry Year	4177	2007.501	15.621	1971	2021
Specific Complementor	4177	.671	.47	0	1

Table 5. Survival Analysis Cloglog Model - The Entry likelihood in New Generations of Dot-matrix Printer Incumbents

VARIABLES	(1) nonimpact	(2) nonimpact	(3) nonimpact enter after 1987	(4) inkjet	(5) inkjet	(6) inkjet enter after 1987	(7) laser	(8) laser	(9) laser enter after 1987
B2C		0.885***			0.783*			0.812***	
		(0.315)			(0.408)			(0.315)	
B2B			-0.647			-0.920**			-0.535
			(0.398)			(0.454)			(0.401)
Org Experience	0.787***	0.859***	0.992***	1.370***	1.458***	1.684***	0.601***	0.650***	0.600**
	(0.218)	(0.220)	(0.292)	(0.366)	(0.371)	(0.444)	(0.205)	(0.206)	(0.252)
Firm Age	-0.165***	-0.191***	-0.253***	-0.114	-0.173**	-0.209**	-0.146***	-0.176***	-0.207***
	(0.0575)	(0.0575)	(0.0791)	(0.0723)	(0.0788)	(0.0869)	(0.0536)	(0.0553)	(0.0729)
Public Firms	0.443	0.711*	0.667	1.441***	1.753***	1.503**	0.491	0.711*	0.847*
	(0.363)	(0.383)	(0.480)	(0.530)	(0.580)	(0.669)	(0.369)	(0.386)	(0.476)
ln(entry_year)	-2.048***	-2.044***	-2.035***	-4.891***	-4.873***	-4.944***	-3.131***	-3.115***	-2.832***
	(0.259)	(0.260)	(0.292)	(0.797)	(0.798)	(0.819)	(0.427)	(0.427)	(0.484)
Specific Complementor	-0.297	-0.591*	-0.484	-0.129	-0.0860	-0.232	-0.324	-0.610*	-0.516
	(0.322)	(0.345)	(0.411)	(0.466)	(0.479)	(0.530)	(0.323)	(0.347)	(0.418)
Constant	-0.989*	-1.196**	-0.702	-1.288	-1.700	-1.115	0.217	0.0872	0.376
	(0.515)	(0.524)	(0.731)	(1.064)	(1.097)	(1.177)	(0.531)	(0.538)	(0.748)
Observations	2,454	2,454	2,237	3,217	3,217	3,165	2,487	2,487	2,255
Log-Likelihood	-213.2	-209.3	-143.4	-129.4	-127.6	-113.4	-225.9	-222.6	-155.6
LR Chi-square	137.5	145.3	106.4	100	103.6	93.64	106.4	112.9	74.40
Prob > Chi2	0	0	0	0	0	0	0	0	0

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6. OLS Regression - The Impact of B2C Experience of Dot-matrix Printer Incumbents on the Overlap of Inkjet and Laser Printers

VARIABLES	(1) Overlap of Inkjet and Laser printers	(2) Overlap of Inkjet and Laser printers
B2C		3.016**
		(1.256)
Inkjet	8.090***	7.963***
	(1.518)	(1.480)
Firm Age	0.458*	0.444*
	(0.257)	(0.250)
Public Firms	5.741***	6.319***
	(1.920)	(1.886)
ln(entry_year)	-0.724	-0.488
	(0.565)	(0.559)
Specific Complementor	-2.609*	-2.864*
	(1.546)	(1.510)
Constant	1.530	0.0766
	(2.346)	(2.364)
Observations	95	95
R-squared	0.491	0.523
Log-Likelihood	-300.2	-297.2
Prob > Chi2	0	0

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7. OLS Regression - The Impact of B2C Experience of Dot-matrix Printer Incumbents on the Length of Market Activities

VARIABLES	(1) Length of stay in nonimpact printers	(2) Length of stay in inkjet printers	(3) Length of stay in laser printers
B2C	9.557***	8.587**	9.288***
	(2.739)	(3.263)	(2.764)
Firm Age	0.660	1.034*	0.613
	(0.546)	(0.576)	(0.543)
Public Firms	8.565**	11.40***	7.558**
	(3.548)	(3.893)	(3.528)
ln(entry_year)	-5.518***	-0.380	-5.272***
	(1.713)	(2.073)	(1.760)
Specific Complementor	-2.451	-6.343	-2.334
	(3.153)	(4.074)	(3.132)
Constant	17.35***	4.395	17.23***
	(4.826)	(5.846)	(4.891)
Observations	60	31	59
R-squared	0.424	0.547	0.403
Log-Likelihood	-221.1	-107.5	-216.9
Prob > Chi2	0.0000115	0.000860	0.0000355

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8. Survival Analysis Cloglog Model - The Survival Likelihood in New Generations of Dot-matrix Printer Incumbents

VARIABLES	(1) nonimpac t	(2) nonimpac t	(3) inkjet	(4) inkjet	(5) laser	(6) laser
B2C		-0.819***		-1.056**		-0.815***
		(0.296)		(0.486)		(0.299)
Org Experience	0.455***	0.587***	0.585***	0.756***	0.440***	0.570***
	(0.147)	(0.162)	(0.211)	(0.239)	(0.147)	(0.162)
Firm Age	-0.0155	-0.0315	-0.119	-0.126	-0.0212	-0.0359
	(0.0516)	(0.0547)	(0.0727)	(0.0772)	(0.0512)	(0.0541)
Public Firms	-0.570	-0.655*	-1.006**	-1.087**	-0.519	-0.611*
	(0.357)	(0.356)	(0.486)	(0.478)	(0.360)	(0.361)
ln(entry_year)	0.472***	0.463***	0.369*	0.275	0.464***	0.449***
	(0.129)	(0.138)	(0.198)	(0.218)	(0.131)	(0.142)
Specific Complementor	0.0107	0.344	0.407	1.025*	0.0601	0.375
	(0.338)	(0.363)	(0.461)	(0.554)	(0.342)	(0.365)
Constant	-4.617***	-4.645***	-3.830***	-3.783***	-4.575***	-4.581***
	(0.694)	(0.758)	(0.978)	(1.041)	(0.696)	(0.763)
Observations	997	997	436	436	973	973
Log-Likelihood	-216.2	-212.3	-106.8	-104.2	-212.9	-209.1
LR Chi-square	21.13	28.87	15.25	20.28	19.37	26.90
Prob > Chi2	0.000767	6.45e-05	0.00935	0.00247	0.00164	0.000151

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9. Survival Analysis Cloglog Model - The Likelihood of Leapfrog

VARIABLES	(1) laser	(2) laser	(3) laser
B2C		0.777**	0.596
		(0.305)	(0.399)
Inkjet	0.729**	0.725**	0.560
	(0.297)	(0.298)	(0.374)
B2C * Inkjet			0.399
			(0.551)
Org Experience	0.655***	0.691***	0.695***
	(0.205)	(0.204)	(0.203)
Firm Age	-0.142***	-0.174***	-0.183***
	(0.0513)	(0.0530)	(0.0542)
Public Firms	0.279	0.474	0.520
	(0.348)	(0.364)	(0.369)
ln(entry_year)	-2.855***	-2.833***	-2.823***
	(0.439)	(0.434)	(0.432)
Specific Complementor	-0.256	-0.527	-0.555*
	(0.308)	(0.334)	(0.337)
Constant	-0.622	-0.716	-0.621
	(0.623)	(0.621)	(0.628)
Observations	2,487	2,487	2,487
Log-Likelihood	-222.7	-219.5	-219.2
LR Chi-square	112.7	119.1	119.6
Prob > Chi2	0	0	0

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

CHAPTER IV. FLYING UNDER THE RADAR: THE IMPACT OF LINGUISTIC AMBIGUITY IN PATENT ON LITIGATION

ABSTRACT

In this study, I focus on the strategic uses of ambiguity by firms, that is to protect themselves from valuable knowledge leakage and detection of potential infringement through information obfuscation. Specifically, I examine a critical type of ambiguity, linguistic ambiguity, and how it is used in patent claims. Linguistic ambiguity tracks the extent to which there are multiple possible interpretations of words used in communication. Given that higher levels of ambiguity increase the difficulty with which stakeholders can understand and critically evaluate the information contained in the communication, I propose that higher levels of patent claim ambiguity will be associated with a lower likelihood of the focal firm being named both a plaintiff and a defendant in a patent infringement lawsuit, but conditional on this occurrence, the focal firm will be less likely to win the litigation.

Keywords:

Patent litigation, linguistic ambiguity, information obfuscation, knowledge leakage

INTRODUCTION

In an organization, ambiguity exists when there is a situation of "having many ways of thinking about the same circumstances or phenomena" (Feldman 1989, p. 5). Ambiguity is defined in terms of a combination of source, message, and receivers. The opposite of ambiguity is clarity. To achieve clarity, an individual as a sender should have an idea and encode the idea into language. Then the receiver should understand the message as it is intended by the sender. During this process, the sender should consider the possible interpretations of the message and try to narrow them down so that the receiver can successfully interpret the message in line with the sender's intention (Eisenberg, 1984).

Ambiguity is related to, but distinguishable from, vagueness. Vagueness in communication refers to "less precise in meaning and impossible to paraphrase precisely" (Channell, 1994; Guo et al., 2017). However, ambiguity refers to "a lack of clarity or consistency, in reality, causality, or intentionality" or "situations that cannot be coded precisely into mutually exhaustive and exclusive categories" (March, 1994). In short, vagueness stems from a lack of precision, whereas ambiguity involves multiple interpretations. For example, the word 'bat' is not vague, but it is ambiguous.

Traditionally, in organizational studies, ambiguity has been viewed as problematic for firms. Internally, ambiguity constrains firms from taking action and change (Alvesson & Sveningsson, 2003; Denis, Langley, & Cazale, 1996; Huxham & Vangen, 2000; March, 1994) and leads to organizational immobility (Denis et al., 2011). When perceived by external audiences, ambiguity can harm firms through loss of reputation (Fombrun & Rindova, 2000), stakeholder trust (Schnackenberg & Tomlinson, 2016), legitimacy (Zuckerman, 1999) and devaluation (Ruef & Patterson, 2009). For example, when disclosing organizational information, firms that strategically remain ambiguous might generate stakeholders' doubts about the integrity of the firm's activity and true purpose (Bernstein, 2012). For instance, in positioning product offerings, firms that intentionally defy to be categorized might suffer from limited access to resources and failure to position themselves in the product market (e.g., Deephouse, 1999; Zuckerman, 2016). Similarly, firms that are not categorized might suffer from devaluation from the media, investors, and analysts (Ruef & Patterson, 2009). Especially for nascent firms, ambiguity might engender devaluation from venture capitalists, angel investors, or other investors, which could be detrimental to new ventures (e.g., Hsu, 2006).

However, scholars have gradually identified the benefits of ambiguity for firms (Abdallah & Langley, 2014; Sillince et al., 2012). Though ambiguity could be harmful to firms, sometimes it is preferable to remain ambiguous by intentionally omitting some contextual cues and allowing multiple interpretations received by the receiver. This perspective suggests that firms strategically leverage ambiguity to advance organizational mission (Eisenberg, 1984). In particular, ambiguity is a valuable resource in engaging organizational actors in strategy and change (Eisenberg & Goodall, 1997). For instance, Jarzabkowski, Sillince, and Shaw (2010) found that ambiguity helps attract constituents' interests and enables them to contribute collectively to strategic action. Besides, a degree of ambiguity provides a common direction to firm actors in strategy-making without limiting their creativity in generating different explanations of multiple interpretations (Eisenberg, 1984; Leitch & Davenport, 2007; Cappellaro, Compagni, & Vaara, 2020).

Firms also have other strategic use of ambiguity that is less well understood: to protect themselves from valuable knowledge leakage and detect potential infringement through information obfuscation. In this study, I examine a critical type of ambiguity, linguistic ambiguity, and how it is used in patent claims and may enable firms to obfuscate information received by competitors. Linguistic ambiguity tracks the extent to which there are multiple possible interpretations of words used in communication (e.g., McMahan & Evans, 2018). Multiple interpretations create confusion and uncertainty about the exact meaning intended by the sender (Levine, 1988). Higher levels of ambiguity increase the difficulty with which stakeholders can understand and critically evaluate the information contained in the communication. Linguistic ambiguity provides firms an opportunity to introduce confusion and obfuscate information contained in patents.

This study employs the context of patent litigation as it is a context where firms may engage when their knowledge is not well protected by patents and when they are detected potential infringement upon other firms' patents. With the patenting process, firms seek to demarcate their territories in a conceptual space—the multidimensional space within which concepts relate to each other (Evans & Aceves, 2016). Patent claims are public documents where firms demonstrate how a new idea differs from existing ideas and products to which the new patent is most similar (e.g., Hall, Jaffe, & Trajtenberg, 2005). Firms face the challenge of striking a balance between being specific and ambiguous in constructing their patent claims. On the one hand, being specific in communicating the underlying technology in patents helps firms claim the knowledge space they occupy and defend better in court (e.g., Kitch, 1977; Somaya, 2012). On the other hand, disclosure of clearly described inventions may not only lead to potential knowledge leakage and provide clues for competitors to do reverse engineering and keep track of the technological development of the focal firm (Magazzini, Pammolli, Riccaboni, & Rossi, 2009) but also alert competitors of the potential to claim infringement (e.g., Polidoro & Toh, 2011; Somaya, 2003). Therefore, firms may not want to communicate these patent claims in such a way as to disclose clear information that can be easily understood by competitors so that they can keep track of the technological development and do imitation or detect potential infringement.

I propose that higher levels of patent claim ambiguity will be associated with a lower likelihood of the focal firm being named both a plaintiff and a defendant in a patent infringement lawsuit, but conditional on this occurrence, the focal firm will be less likely to win. To test these hypotheses, I examine the ambiguity levels of patent claims in patents and their association being drawn into litigation. As patent infringement depends highly on the commercialization of products, and lots of patent infringement lawsuits occur because the defendant produced a product that violates an existing patent that a plaintiff owns, it is necessary to introduce an additional context where in all cases, the patent validity is being challenged in a lawsuit. Therefore, I employ the context of Inter Partes Review (IPR), which only includes patents that are involved in IPR lawsuits. By doing this, I directly examine how linguistic ambiguity affects the contestation of the conceptual space. Furthermore, since the ambiguity of patent claims is a choice by firms and thus might lead to potential endogeneity problems, I plan to do a natural experiment on eBay's patent case in 2006.

This study intends to make two contributions. First, I advanced our understanding of ambiguity in organizational studies. Ambiguity is an important topic that has been studied in multiple disciplines, such as communication studies (Eisenberg, 1984), linguistics (MacDonald, Pearlmutter, & Seidenberg, 1994), and political science (Shepsle, 1972). In organizational studies, a large body of literature focuses on the role of strategic ambiguity in strategy-making and organizational change (e.g., Abdallah & Langley, 2014; Sillince et al., 2012; Eisenberg & Goodall, 1997). I complement the study of ambiguity in organizations by focusing on the role of linguistic ambiguity in information obfuscation. The concept of linguistic ambiguity unlocks the theoretical property of multiple meanings. Multiple meanings of a single set of information may lead to receivers' confusion and uncertainty about the exact meaning intended by the sender (e.g., Levine, 1988; McMahan & Evans, 2018). Hence, this paper contributes to the ambiguity literature by opening up the examination of the potential for information obfuscation and knowledge protection.

Second, this study also contributes to the literature on knowledge protection (e.g., Hussinger, 2006; Somaya, 2012) and litigation likelihood (e.g., Somaya, 2000; 2003;

Schweizer, 1989; Priest & Klein,1984). Researchers have long acknowledged that patents are a significant type of imitation barrier and a way to protect knowledge (e.g., Mahoney & Pandian, 1992; Rumelt, 1984; Somaya, 2012). However, patents do not necessarily provide the patent owner an affirmative right to use the patented technology if the technology infringes other patents, nor do they eliminate situations that competitors imitate or innovate around the patents (Mansfield, Schwartz, & Wagner, 1981). In this paper, I try to show that the level of ambiguity in patent claims influences how effective patents are in protecting a firm's technological knowledge through information obfuscation. Furthermore, I also suggest that ambiguous patent claims reduce the likelihood of engaging in patent infringement lawsuits, no matter as a plaintiff or a defendant.

THEORETICAL FRAMEWORK

Linguistic ambiguity

Linguistic ambiguity denotes the extent to which there are multiple possible interpretations of language (e.g., McMahan & Evans, 2018). Multiple meanings generate receivers' confusion and uncertainty about the exact meaning intended by the sender (Levine, 1988). Uncertainty increases the difficulty in understanding the information contained in a context and interpreting the true meaning of that information (e.g., Guo, Yu, & Gimeno, 2017). Sometimes multiple meanings are generated with plans. We have long known the potential benefits of ambiguous strategic actions. Strategic ambiguity is a valuable way for the author to create multiple meanings (i.e., polysemy) by purposefully choosing sentences, with the hope of resulting in two or more otherwise conflicting groups of readers converging in praise of a text (Weick, 1997). For example, when making sense of a music video by the rock-star Madonna, readers of Playboy interpret it as a "sex kitten" display for their entertainment, but young girls treat it as a brave woman's aggressiveness to break the conventions of patriarchy (Ceccarelli, 1998). In the study of robust action, Padgett and Ansell (1993) catalogued the behavior of Cosimo de' Medici as an actor who showed a sphinxlike character to harness the power in network holes by generating multivocality, a single action that could be interpreted coherently from multiple perspectives at the same time.

Ambiguously conveyed information would likely generate multiple meanings and leave room for audiences to have various interpretations (e.g., Ceccarelli, 1998). People would find it challenging to learn the true meanings of the information communicated in an ambiguous manner (e.g., McMahan & Evans, 2018). By extension, firms, which are made up of teams of decision-makers interpreting information, would likely have these same difficulties. Thus, when firms intentionally design ambiguous messages in public documents, competitors would likely find it hard to get clues of valuable knowledge and information in those documents. Therefore, strategic ambiguity allows firms to hide valuable knowledge and obfuscate information from potential competitors.

Disclosure of technological information in patent claims

With the patenting process, firms seek to demarcate their territories in a conceptual space—the multidimensional space within which concepts relate to each other (Evans & Aceves, 2016). To be more specific, firms need to demonstrate the novelty of their new idea in patent claims, that is, to communicate in a written document how the new idea is different from relevant existing ideas and products (e.g., Hall, Jaffe, & Trajtenberg, 2005). Communicating the underlying technological and scientific information contained in the patent helps the firms claim the knowledge space they occupy, thereby temporarily excluding others from producing an invention within the boundaries that are delineated by the patent claims (e.g., Kitch, 1977; Somaya, 2012). More importantly, some markets for technologies could be highly fragmented, which is patent ownership rights to external technologies are widely distributed.

Furthermore, some groups have created patenting pools to get around the patent fences. Thus, the conceptual spaces can be divided up and contested, leading firms to claim their ideas in a strategic way to prevent others from patenting (Ziedonis, 2004).

Linguistic ambiguity in patent claims and information obfuscation

The context of patent claims naturally creates a tradeoff that firms must navigate. Firms face a tension between being specific and ambiguous when drafting patent claims. On the one hand, a firm may benefit by specifically demonstrating the underlying technology and the novelty of the idea because this increases the likelihood that the patent examiner will grant the patent eventually. Clearly described patents also help firms better claim their knowledge space (e.g., Scotchmer & Green, 1990). As a patent may be cited in litigation lawsuits, more clearly defined technologies and their legal boundaries within a patent help the patent owner to defend their own knowledge space better and thus leads to higher predictability of the outcome of the lawsuit (Humphery-Jenner et al., 2019).

On the other hand, there may be an advantage to having more ambiguous patent claims. One important reason is to have broader claims (e.g., Liivak, 2018). In general, the breadth of the claims in a patent is positively associated with the scope of protection a patent can hold (e.g., Gilbert & Shapiro,1990). Besides seeking a broader scope of knowledge space, the use of ambiguous language in patent claims also has other intended or unintended consequences.

Ambiguity leads to the obfuscation of technological information. Less clearly described technologies and their legal boundaries will make rivals less able to decipher the technological nature of the invention and thus engage in reengineering and predatory actions (e.g., Magazzini, Pammolli, Riccaboni, & Rossi, 2009). Similar evidence could be found in the field of linguistics. Researchers showed that the strategic use of language could serve to obfuscate information (e.g., Li, 2008). For instance, researchers show that managers intentionally use complex language in corporate disclosures to increase the external audiences' information processing costs and delay the market reaction to the news. Specifically, researchers found that linguistic complexity has a latent component of obfuscation, which is positively associated with information asymmetry (Bushee, Gow, & Taylor, 2018).

The likelihood of being a plaintiff in patent litigation

In the context of patent claims, ambiguity in patent claims likely leads to technological information obfuscation. As firms are required to disclose the underlying technology of an invention in the patent claims, it is likely that being ambiguous in constructing their patent claims generates multiple interpretations and leaves audiences confused about the true meanings of the ideas behind an invention. To be more specific, ambiguous patent claims increase the difficulty for competitors to understand the knowledge contained in the patent and provide fewer clues for them to reverse engineer existing production components. For competitors, the information processing cost increases if they want to imitate or innovate around the focal firms' products. Accordingly, the likelihood that competitors successfully infringe upon the focal firm's patent will be decreased. Thus, there are fewer situations when the focal firm needs to sue others for patent infringement.

Furthermore, a more ambiguously claimed patent might reduce the focal firm's incentive to sue others since ambiguous patent claims lower the predictability of the outcome of a lawsuit (e.g., Datar, Amore, & Fosfuri, working paper; Humphery-Jenner et al., 2019). In court, the more ambiguous the patent claims within a patent cited in an infringement lawsuit, the more likely the judge's interpretations of the claims would deviate from the core text. Ambiguously described patent claims weaken a firm's ability to defend ownership of the idea space claimed in the patent. A firm has less incentive to sue others if it has a low expectation of winning the lawsuit.

In general, firms might avoid engaging in patent litigation because it has some negative influences. Patent litigation is the legal process that unfolds when the patent owner enforces its right over the patent invention by suing another for manufacturing or selling the invention without permission. In general, patent litigation is extremely costly, disruptive, and time-consuming (Encaoua & Lefouili, 2005; Shane & Somaya, 2007). Besides the legal fees, firms engaged in patent litigation might also face high losses from declining firm valuations and risks surrounding the loss of patent validity (Bhagat, Brickely, & Coles, 1994; Lerner, 1995). Even firms that win lawsuits face the opportunity costs of lost business and management distraction. (e.g., Bessen & Meurer, 2005). Based on the above reasons, we suggest:

> *Hypothesis 1. The higher the level of ambiguity of patent claims in a firm's patent, the lower the likelihood the firm will file a patent infringement lawsuit concerning the patent against other firms.*

The likelihood of being a defendant in patent litigation

In the process of preparing patent claims, firms would likely strategically be ambiguous in communicating the ideas contained in a patent to reduce competitors' understanding and awareness of the potential infringement (e.g., Polidoro & Toh, 2011; Somaya, 2003), thus reducing the likelihood of engaging in patent litigation. Specifically, the structure of the patent claims matters a lot in influencing the readers' understanding of the information contained in the claims (e.g., Shinmori et al., 2003; Parapatics & Dittenbach, 2011). For example, Japanese patent claims usually have low readability because they are structured so that multiple sentences are coerced into one sentence. This is caused by the high structural complexity of sentences and the use of multiple complicated terms in the claims. In other words, when patent claims are described in one sentence with a peculiar style and wording, they are difficult to understand for external audiences (Shinmori et al., 2003). In contrast, researchers have shown that the analysis of patent claims can be improved mainly by using natural language process techniques to decompose the claims into smaller units. This will facilitate patent information processing since patent claims can be further analyzed, structured, and visualized (Parapatics & Dittenbach, 2011).

When firms use ambiguous language in constructing their patent claims, they intentionally generate multiple interpretations and confuse competitors about the true meanings behind an invention's ideas. An ambiguous communication obfuscates information contained in patent claims. A higher level of ambiguity of patent claims within a patent suggests that the potential competitors would be uncertain about the boundaries the focal firm is drawing around the idea space in the claim. Thus, competitors would not easily detect potential infringement by the focal firm. Since the probability of litigation also depends on the expectation to win the litigation, firms would have more incentives to sue potential infringers since they expect a higher likelihood of winning the lawsuit as a plaintiff if the defendant's patent is ambiguously claimed. However, we believe ambiguity will play a greater role in obfuscating information and hiding clues of potential infringement than motivating competitors to file infringement lawsuits. Accordingly, we predict:

> *Hypothesis 2. The higher the ambiguity of the patent claims in a firm's patent, the lower the likelihood that a firm will be named a defendant in a lawsuit concerning the patent.*

The likelihood of winning the lawsuits

If a patent owner believes that another firm infringes its patent, the patent owner may file a lawsuit in court. The patent owner must prove that it is more likely than not that the defendant infringed the patent. If the defendant does not admit the factual allegations presented by the plaintiff, it must provide proofs that its patent did not infringe the asserted patent. Usually, both parties in a lawsuit will disagree about the meaning of key terms in the claims, which define the legal boundaries that the patent delineates. Therefore, the precise meaning attributed to the language in patent claims within a patent will often largely influence the lawsuit's outcome. The judges in court, at their discretion, need to resolve the disagreement and decide whether a patent is found to be infringed or invalid (Kolodney, 2019).

Under ambiguity, the audience would interpret the document according to their own "idiosyncratic intuitions, tastes, mental heuristics, and skills" (McMahan & Evans, 2018). The more ambiguous the patent claims within a patent cited in an infringement lawsuit, the more likely the judge's interpretations of the claims would deviate from the core text. That is to say, clear and specific claims help the firm better defend ownership of the idea space in its patent in patent litigation than ambiguous claims. Thus, we argue:

> *Hypothesis 3. Conditional on a patent infringement lawsuit being filed, the higher the ambiguity of the patent claims in a patent, the lower the probability the firm will win the lawsuit concerning the patent."*

EMPIRICAL CONTEXT AND RESEARCH DESIGN

Patent litigation context

In the general litigation context, for empirical analysis, I employ data on firm patents and patent litigation between 1976 and 2015. I draw information on firm patents from the *PatentsView* database, which covers published patent applications (2001- most recent update) and granted patents (1976-most recent update). In total, there are 6,831,036 patents in the *PatentsView* database. I obtained the full text of patent claims and patent abstracts (see Figure 1 for an example of the text we extracted from the patent). I draw data on patent litigation activity from US District Court Electronic Records (Marco et al., 2017). It contains metadata information on 74,629 cases across all district courts from 1963 to 2015. I focus on the patent as the unit of analysis to investigate a firm's patent and its litigation experiences. I plan to match the firm patent and litigation data based on each unique patent number, which would eventually provide us with a sample of patent and litigation information for each firm from 1976 to 2015. To be more specific, I plan to identify each unique patent number and its associated patents portfolio in the *PatentsView* database. Then I will merge the patent data with the litigation data based on each patent number. Eventually, I plan to get a final database with patent observations.

Inter partes review (IPR) lawsuits

In the general litigation context, many cases occur because the defendant produced a product that violates a plaintiff's existing patent. Patent infringement depends highly on the commercialization of products, not the patent itself. To be more specific, the infringement of a patent occurs when a firm launches a product that is based on a patent held by another firm. Thus, in those cases, a litigation event may occur regardless of the ambiguity of the patent, thereby preventing us from examining the link between the linguistic ambiguity of patent claims and the occurrence of being named a defendant in a lawsuit. Therefore, a potential problem with the current general litigation context is that we might over-attribute the litigation likelihood to the ambiguity in patent claims.

This indicates that we should look for an additional context where we can make sure the patent is a reason for an infringement lawsuit. To examine how linguistic ambiguity affects the contestation of the conceptual space more directly, we focused on the subset of patent litigation events that involved an Inter Partes Review (IPR).

IPRs are parallel proceedings in the United States Patent and Trademark Office (USPTO), as compared to litigation trials that take place at the federal district courts. IPRs are filed after the patent has already been granted. Specifically, if a firm thinks an external patent claimed the knowledge space that is already claimed in its own patents, it could initiate an IPR to challenge the validity of the external patent. IPR proceedings were introduced by the America Invents Act in September 2012 to resolve complex scientific issues associated with a patent. IPR was designed to be less expensive and less time-consuming than district court proceedings (Espinosa, 2017). Given that larger firms have a financial advantage in bearing the high costs of federal court litigation, IPR alleviates smaller firms' financial burden that results from litigation. In sum, IPRs were created to improve patent quality by offering an efficient lower-cost way to challenge weaker patents (Mahaseth, 2018).

IPRs can be initiated by anyone other than the patent owner to challenge the validity of granted patent claims based on patents or printed publications that predate the patent's filing date. Most often, IPRs are issued by firms that have been sued for patent infringement because accused infringers can argue that the asserted patent is invalid and, thus, should never have been granted (Love, Miller, & Ambwani, 2018). Therefore, in IPR proceedings, a firm could contest another patent by claiming that the asserted patent violates the prior art and, thus, should be invalid.

IPR patents provide a better context to examine the effect of patent claim ambiguity on firms' ability to protect their idea spaces. Specifically, by identifying each patent involved in the IPRs, we can link the linguistic ambiguity of patent claims in one patent and its likelihood of winning an IPR proceeding. IPR is becoming a popular pathway for challenging patent validity (Mahaseth, 2018). Until 2018, over 7,600 IPR petitions were filed with the Patent Trial and Appeal Board (PTAB). I plan to get data on PTAB proceedings from Unified Patents, Inc, a commercial database containing information on individual petitions. This data allows us to identify each patent challenged in each proceeding. It also provides information about the proceedings' filing date and outcomes. Therefore, I can directly measure the linguistic ambiguity of patent claims in these patents and the possibility that it wins in an IPR.

Natural experiment design: the case of eBay vs. MercExchange

Given that being ambiguous or not in a patent claim is a choice for firms, our analysis might be subject to potential endogeneity issues. At the heart of these issues is the possibility that there could be confounding variables that may affect both a firm's decision to have ambiguous patent claims and the likelihood of a firm being sued for patent infringement. Therefore, I plan to perform a natural experiment to offset endogeneity concerns. I focus on the patent litigation case of eBay vs. MercExchange and its associated change in the court's discretion and the likelihood of injunction relief.

eBay Inc. v. MercExchange, L.L.C., 547 U.S. 388 (2006), is a landmark case in patent litigation. Under existing Federal Circuit law of the United States, there is a general rule that courts will issue permanent injunctions against patent infringement once a defendant has been determined to infringe a valid patent. However, in eBay's case, the Supreme Court determined that injunctive relief in patent cases should not be granted automatically based on a finding of patent infringement. Instead, the district courts should consider a four-part test in deciding whether to issue injunctive relief. In other words, patent owners must demonstrate entitlement to a permanent injunction under a four-factor test (275 F.Supp.2d, at 711) in order to seek equitable relief. To be more specific, a plaintiff must demonstrate "(1) that it has suffered an irreparable injury; (2) that remedies available at law, such as monetary damages, are inadequate to compensate for that injury; (3) that, considering the balance of hardships between the plaintiff and defendant, a remedy in equity is warranted; and (4) that the public interest would not be disserved by a permanent injunction" (eBay III, 547 U.S. at 391).

Since the Supreme Court issued its eBay decision in 2006, the district courts are exercising greater discretion in analyzing the four-factor test and deciding whether or not to issue injunctions. Meanwhile, it is becoming difficult for many successful patent plaintiffs to obtain a permanent injunction even though they are awarded monetary damages. Thus, in some patent litigation cases where the plaintiff wins but is not granted injunctive relief, it is likely that the defendants who had been found patent infringement might continue to infringe the patents at issue. The only cost for the defendant to lose the litigation is to pay monetary damages. Thus, being detected and even sued for patent infringement may be less harmful to firms. As a consequence, the eBay case could arguably reduce firms' motivations to be ambiguous in patent claims in a patent so as to avoid being detected as potential infringement.

Instead, firms would find it less beneficial to have ambiguous patent claims in a patent because it would be more difficult for the firm to defend their knowledge space with ambiguously communicated ideas once the patent is cited in a lawsuit. Furthermore, the district courts' stronger discretion after the eBay case also motivates defendants to defend themselves in court by having less ambiguously communicated patent claims. Because a higher standard in determinations of injunctions is unlikely to cause an increase in patent litigation activity, the difficulty in obtaining an injunction should work against us finding our main hypothesized effect. It would therefore appear that the eBay case provides an appropriate natural experiment for assessing the effect of ambiguity in patent claims in a patent on litigation likelihood. In essence, the eBay vs. MercExchange case swung the tradeoff firms are making from ambiguity is beneficial in avoiding being detected infringement to it is less clearly beneficial in that being detected infringement and even losing the lawsuit is less severe for defendants.

A good natural experiment should have a shock that is unexpected, exogenous, and transparent in assigning the treatment group (Meyer, 1995). Specifically, the shock should allow researchers to identify exogenous variation in the explanatory variables and rule out the possibility that firms make decisions based on expectations of the shock (Heckman & Smith, 1999). Therefore, to make sure the eBay case could be a good natural experiment, we examined relevant legislative reports, legal reviews, and academic studies (Fues, 2007; Stiefel, 2016; Chao, 2008) and found that there was a huge debate on the permanent injunction issued to eBay among the district court, the Federal Circuit, and the Supreme Court. The courts did not draw previous cases as evidence but instead discussed the interpretations of the "general rule" about the permeant injunction[14]. Therefore, the Supreme Court's eBay decision should be an unexpected shock and, thus, an exogenous source of variation in firms' decisions to use ambiguous language in patent claims.

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[14] eBay Inc. v. MercExchange, L.L.C., 547 U.S. 388 (2006)

The eBay natural experiment is suitable for a difference-in-differences (DID) analysis. I assign firms that have patents in the United States to the "treated group" and assign firms that have patents in other countries (We are planning to obtain patent data granted in Europe and Asia where there is no change in the standard of determinations of injunctive relief) to the "comparison group" in that the courts in these countries did not enforce the four-factor test to issue injunctions. DID establishes a causal effect by identifying the before-to-after difference in the treatment group, netting out trends from the comparison group. The parallel-trend assumption in DID requires that countries that enforce and do not enforce a four-factor test share parallel trends prior to the passage of the four-factor test in terms of the outcome of interest. The second assumption in DID is common shocks, which suggest that exogenous forces affect treatment and comparison groups equally in the post-intervention period. While parallel-trend assumption and common shocks assumption is ultimately untestable, I plan to do several examinations to provide evidence that is in line with them.

Dependent variables

In our analyses, I utilized six dependent variables to capture a firm's ability to defend its idea spaces. Specifically, we have three dependent variables in the litigation context (the same as in the natural experiment context) and the Inter Partes Review context, respectively. In the litigation context, the first dependent variable is *the likelihood of suing others*. It is a binary variable that equals one if the firm is named as a plaintiff in a lawsuit concerning that patent and zero otherwise. The second dependent variable is the *failure to avoid litigation.* It is a binary variable that equals one if the firm is named as a defendant in a lawsuit concerning that patent and zero otherwise. The third dependent variable, *losing litigation*, is a binary variable that equals one if the firm lost a lawsuit, no matter as a defendant or plaintiff, zero otherwise. I also plan to categorize cases by whether settlements occurred and do two subsample analyses.

In the Inter Partes Review context, the dependent variable, *losing IPR*, is measured as a binary variable which equals one if the firm lost a lawsuit that involves IPR proceedings.

Independent variable

The independent variable, *ambiguity of patent claims*, is of central interest in our study. We follow McMahan and Evans's measure (2018) of linguistic ambiguity by introducing the information-theoretic entropy formula.

$$H(X) = -\sum_{i=0}^{k} pk\log_2(pk) \quad (1)$$

$\Pr(M|ti, ci) : M \in \{m0,\ m1,\ \ldots\}$ denotes the way we think about words as a set of discrete, enumerable, and identifiable objects; We represent the set of lexical tokens with $\mathrm{T} \in \{\mathrm{t0}, \mathrm{t1}, \ldots\}$ and the set of linguistic contexts with $\mathrm{C} \in \{\mathrm{c0}, \mathrm{c1}, \ldots\}$.

The concept of "entropy" comes from information theory. It indicates "the level of statistical uncertainty in a discrete probability distribution" (Shannon, 1948). More specifically, entropy denotes the unique information content from a random variable. It measures the unpredictability associated with that variable' s outcomes (McMahan & Evans, 2018). This distribution above (1) represents the set of meanings held by a word as used in the corpus, along with the relative probability for each of those meanings conditional on each linguistic context. By incorporating the multiple meanings of a word and the probability of each meaning in a given linguistic context, this formula measures the ambiguity of a linguistic context.

Employing this formula to patent claims, we can efficiently model how ambiguous a patent claim is in communicating the technological idea behind an invention, suggesting the competitors' and the judge's uncertainty about the sense of that patented idea. For example, in an abstract of a patent related to 3D printing, "…producing three-dimensional objects and auxiliary systems…continuously printing radially about a circular and/or rotating build table using multiple printheads…optionally using multiple build tables…", the formula will calculate each word's meanings and the relevant possibility of each meaning in this linguistic context. When we include more patent abstracts and claims, we are actually enlarging the linguistic context, resulting in a more precise measure of linguistic ambiguity.

Control variables

I control for variables that could be related to patent ambiguity and the likelihood of patent litigation. At the patent level, I control for the *technological complexity of a firm's patent*. Given that some technologies may be less codified than others and would be patented in an ambiguous way by nature, it is important to include a patent's technological complexity as it captures the nature of technology and, therefore, might influence the ambiguity level of a patent. As it is difficult to establish a context-free measure of technological complexity (Singh, 1997), I follow most studies of complexity and use conceptual complexity measures that compare the relative complexity of a technology to that of a closely related technology (e.g., Kline, 1991).

I also consider the *patent distinctiveness of a firm's patent*. The distinctiveness of a patent indicates whether the invention is a technological breakthrough. A breakthrough discovery is a distinct and high impact because it recombines existing components in new ways or rearranges previous combinations using novel relationships (Funk & Owen-Smith, 2012; Henderson & Clark, 1990). A patent with a high level of distinctiveness would be more valuable and thus more likely to be imitated by competitors than a less distinct patent, no matter how ambiguous the way it is claimed. We follow Funk and Owen-Smith's (2012) measure of patent distinctiveness which incorporates a focal patent and its forward citations: $Dt = \frac{\sum_i(-2 f_{it} b_{it} + f_{it})}{n_t}$, where f_{ij} equals 1 when a patent i cites the focal patent (class f) (0 otherwise); b_{ik} equals 1 when a patent i cites any focal patent prior art (class b) (0 otherwise); n is the number of forward cites in i.

Firms' patents may feature other aspects that reduce confusion. Specifically, figures may provide information outside of the texts that we examine. The variable *count of figures in* *the patent claims of a firm's patent* might provide information that is not included in the textual patent claims but also discloses technological information to competitors. In the same vein, to control for the amount of information contained in a patent claim, I also include *the average length of patent claims of a firm's patent* by calculating the mean of the total number of words in each patent claim. *The number of citations of a firm's patent* is also included because citation counts indicate the value of a patent. Firms would place more importance on being ambiguous in highly valuable patents as they are more likely to contain technological and scientific knowledge that is also valuable to competitors.

In addition, I include *the number of patent classes in a firm's patent* using the International Patent Classification (IPC). IPC indicates different areas of technology to which a patent pertains. In general, firms with patents in multiple technological areas would also be more likely to engage in patent litigation than firms that only patent in limited technological fields.

I consider controlling *patent breadth*. One important reason for being ambiguous in patents is to have broader claims (e.g., Liivak, 2018). In general, the breadth of the claims in a patent is positively associated with the scope of protection a patent can hold (e.g., Gilbert & Shapiro,1990). For instance, a firm could claim in a patent that its innovation applies to the electronic device, while in reality, it might only apply to smartphones. Gilbert and Shapiro (1990) suggested that a broader patent allows the innovator to earn a higher flow rate of profits during the patent's lifetime. I follow their measure of *patent breadth* using the flow rate of profits available to the patentee while the patent is in force.

Some other variables might also influence the likelihood and outcomes of patent litigation. Specifically, *the size of the firm*, measured as the log of the number of employees, might change how likely a firm would be involved in litigation. Larger firms are more likely to be engaged in patent litigation actions. I include *firm age* measured as year t minus the founding year. Besides, I also control for the *firm's capital intensity measured as a log of the net plant and equipment ratio* to the number of employees (Hall & Ziedonis, 2007). Filing patent litigation is costly and might be a burden for financially strained companies. I also include the *R&D intensity of the firm* measured as a log of the ratio of current R&D spending to employees, which captures the importance of knowledge assets to the firm.

As for industry-level variables, I include the firm's *number of industries* measured by the number of different four-digit SIC codes. Besides, it is conceivable to include the average *market overlap* between the focal firm and the plaintiffs in all lawsuits using the count number of the same Standard Industrial Classification (SIC) codes. Market overlap indicates the intensity of competition between the two parties in patent litigation, thus influencing the likelihood of patent litigation.

Estimation method

General patent litigation and inter partes review

The empirical analysis pertains to the patent level. We estimated the impact of the ambiguity level of patent claims in a firm's patent on the likelihood that a firm would file patent infringement lawsuits against others (Hypothesis 1), would be sued in patent infringement lawsuits (Hypothesis 2), and win the lawsuits (Hypothesis 3). In the IPR context, the unit of analysis is also at the patent level, as the variables are measured only based on firms' patents that are involved in IPR proceedings. Each of the control variables described above references a specific patent. Since the dependent variables in the hypotheses are binary variables, I employ the logistic regression technique, which is suitable for modeling categorical dependent variables. As the number of realized litigations is relatively small, I also plan to use rare events logistic regression as a robustness check.

The eBay natural experiment

To estimate the effect of the enforcement of the four-factor test in patent cases in the US in 2006 on the likelihood that a firm *i*, in country *c,* at time *t*, is named a defendant in lawsuits concerning its patents (Hypothesis 1), I estimate the following model:

$$yct = \alpha(eBay \, * \, Post2006) + \beta eBay + \gamma Post2006 + \delta Z + ejct \qquad (2)$$

In this equation, y is the total number of times a firm is named as a defendant in patent infringement lawsuits. (eBay*Post2006) is the treatment; eBay is the dummy variable that takes a value of '1' for firms in the US and '0' otherwise, and Post2006 is a dummy that takes the value of '1' for firms that have patents in the period after 2006 and '0' otherwise. Furthermore, Z is the vector of controls, including country-level fixed effects. Therefore, this regression estimated the change in the US and the change in comparison countries and then took the difference between those two differences.

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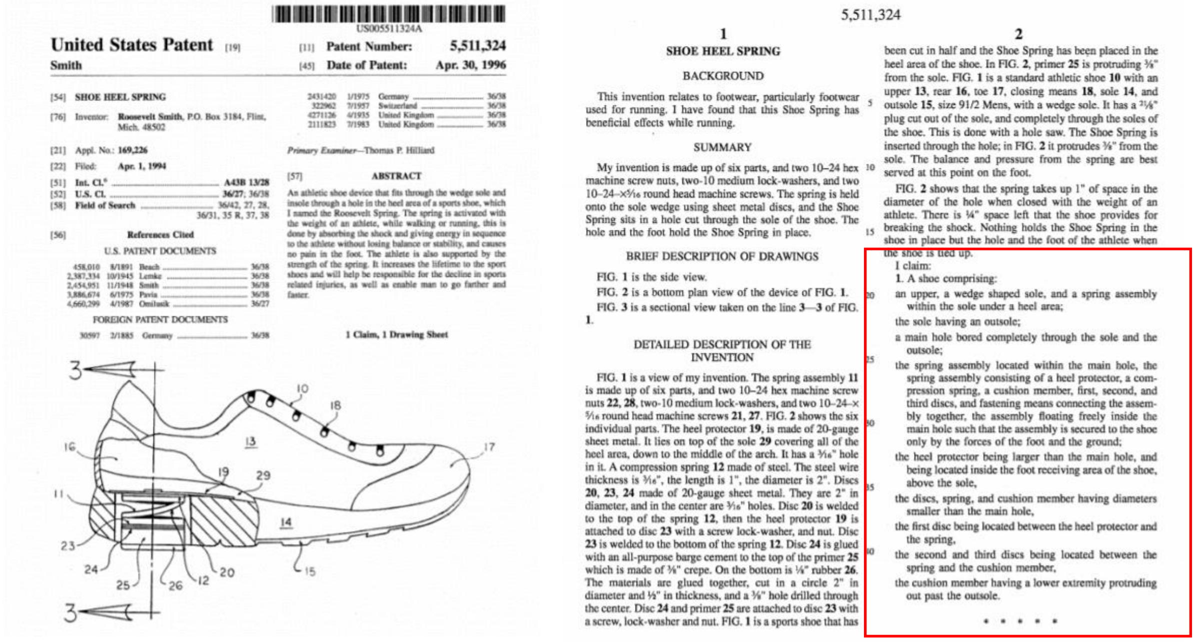
Appendix A1: Examples of Patent Abstract and Patent Claims Within a Patent



US005511324A

United States Patent [19]
Smith

[11] Patent Number: 5,511,324
[45] Date of Patent: Apr. 30, 1996

[54] SHOE HEEL SPRING

[76] Inventor: Roosevelt Smith, P.O. Box 3184, Flint, Mich. 48502

[21] Appl. No.: 169,226

[22] Filed: Apr. 1, 1994

[51] Int. Cl.[6] A43B 13/28
[52] U.S. Cl. 36/27; 36/38
[58] Field of Search .... 36/42, 27, 28, 36/31, 35 R, 37, 38

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Primary Examiner—Thomas P. Hilliard

[57] ABSTRACT

An athletic shoe device that fits through the wedge sole and insole through a hole in the heel area of a sports shoe, which I named the Roosevelt Spring. The spring is activated with the weight of an athlete, while walking or running, this is done by absorbing the shock and giving energy in sequence to the athlete without losing balance or stability, and causes no pain in the foot. The athlete is also supported by the strength of the spring. It increases the lifetime to the sport shoes and will help be responsible for the decline in sports related injuries, as well as enable man to go farther and faster.

1 Claim, 1 Drawing Sheet

5,511,324

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SHOE HEEL SPRING

BACKGROUND

This invention relates to footwear, particularly footwear used for running. I have found that this Shoe Spring has beneficial effects while running.

SUMMARY

My invention is made up of six parts, and two 10–24 hex machine screw nuts, two-10 medium lock-washers, and two 10–24–×5/16 round head machine screws. The spring is held onto the sole wedge using sheet metal discs, and the Shoe Spring sits in a hole cut through the sole of the shoe. The hole and the foot hold the Shoe Spring in place.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is the side view.

FIG. 2 is a bottom plan view of the device of FIG. 1.

FIG. 3 is a sectional view taken on the line 3—3 of FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a view of my invention. The spring assembly 11 is made up of six parts, and two 10–24 hex machine screw nuts 22, 28, two-10 medium lock-washers, and two 10–24–× 5/16 round head machine screws 21, 27. FIG. 2 shows the six individual parts. The heel protector 19, is made of 20-gauge sheet metal. It lies on top of the sole 29 covering all of the heel area, down to the middle of the arch. It has a 3/16" hole in it. A compression spring 12 made of steel. The steel wire thickness is 3/16", the length is 1", the diameter is 2". Discs 20, 23, 24 made of 20-gauge sheet metal. They are 2" in diameter, and in the center are 3/16" holes. Disc 20 is welded to the top of the spring 12, then the heel protector 19 is attached to disc 23 with a screw lock-washer, and nut. Disc 23 is welded to the bottom of the spring 12. Disc 24 is glued with an all-purpose barge cement to the top of the primer 25 which is made of 3/8" crepe. On the bottom is 1/4" rubber 26. The materials are glued together, cut in a circle 2" in diameter and 1/2" in thickness, and a 3/8" hole drilled through the center. Disc 24 and primer 25 are attached to disc 23 with a screw, lock-washer and nut. FIG. 1 is a sports shoe that has

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been cut in half and the Shoe Spring has been placed in the heel area of the shoe. In FIG. 2, primer 25 is protruding 3/8" from the sole. FIG. 1 is a standard athletic shoe 10 with an upper 13, rear 16, toe 17, closing means 18, sole 14, and outsole 15, size 91/2 Mens, with a wedge sole. It has a 21/8" plug cut out of the sole, and completely through the soles of the shoe. This is done with a hole saw. The Shoe Spring is inserted through the hole; in FIG. 2 it protrudes 3/8" from the sole. The balance and pressure from the spring are best served at this point on the foot.

FIG. 2 shows that the spring takes up 1" of space in the diameter of the hole when closed with the weight of an athlete. There is 1/4" space left that the shoe provides for breaking the shock. Nothing holds the Shoe Spring in the shoe in place but the hole and the foot of the athlete when the shoe is tied up.

I claim:

1. A shoe comprising:

an upper, a wedge shaped sole, and a spring assembly within the sole under a heel area;

the sole having an outsole;

a main hole bored completely through the sole and the outsole;

the spring assembly located within the main hole, the spring assembly consisting of a heel protector, a compression spring, a cushion member, first, second, and third discs, and fastening means connecting the assembly together, the assembly floating freely inside the main hole such that the assembly is secured to the shoe only by the forces of the foot and the ground;

the heel protector being larger than the main hole, and being located inside the foot receiving area of the shoe, above the sole,

the discs, spring, and cushion member having diameters smaller than the main hole,

the first disc being located between the heel protector and the spring,

the second and third discs being located between the spring and the cushion member,

the cushion member having a lower extremity protruding out past the outsole.

* * * * *

The above figures show two examples of the patent abstracts and claims we obtained from the *PatentsView* database. Here are some characteristics of patent claims and abstracts:

- The claim should appear after the detailed description of the invention. According to the current practice, each claim usually starts with "I claim," "The invention claimed is," or the substantial equivalent thereof.
- An independent claim is a stand-alone claim that contains a preamble and all of the elements necessary to define the invention. It could be a claim for a "thing," a method of making a "thing," and a method of using a "thing." Independent claims refer back to and further limit another claim or claims in the same application.
- There could be multiple patent claims within a specific patent, and we would capture all of them.
- Besides textual descriptions, there are also figures within a patent claim. As a control variable, we count the number of figures within the patent to proxy for the possibility that vital information could be revealed in these drawings.