Competitive initiatives and vulnerability: The moderating roles of resource portfolios, open innovation, and network position

Chihyi Su  
Shenzhen University  
College of Management  
chihyisu@163.com

Jianwu Jiang  
Shenzhen University  
College of Management  
jwjiang@szu.edu.cn

Bou-Wen Lin  
National Taiwan University  
College of Management  
bwlin@ntu.edu.tw

Abstract

As firms initiate competitive attacks, they must also adopt defensive strategies to reduce their vulnerability to rivals' threats. This study focuses on firms' resource-based competitive actions and examines how technological diversity, open innovation strategies, and network position moderate the effects of competitive actions on firm performance. Using a sample of 184 firms in the US communications equipment industry, we show that a more-diversified technological portfolio and a less-crowded technological network enhance the strength of competitive initiatives, whereas inbound open innovation plays a critical role in mitigating the effects of vulnerability on firm performance. This study contributes to competitive dynamics by developing an integrated perspective of competitive behavior within the broad context of resource-based view, open innovation, network position, and firm performance.
Competitive initiatives and vulnerability: The moderating roles of resource portfolios, open innovation, and network position

ABSTRACT

As firms initiate competitive attacks, they must also adopt defensive strategies to reduce their vulnerability to rivals’ threats. This study focuses on firms’ resource–based competitive actions and examines how technological diversity, open innovation strategies, and network position moderate the effects of competitive actions on firm performance. Using a sample of 184 firms in the US communications equipment industry, we show that a more-diversified technological portfolio and a less-crowded technological network enhance the strength of competitive initiatives, whereas inbound open innovation plays a critical role in mitigating the effects of vulnerability on firm performance. This study contributes to competitive dynamics by developing an integrated perspective of competitive behavior within the broad context of resource-based view, open innovation, network position, and firm performance.

Keywords: Competitive initiative, vulnerability, technological diversity, network position, open innovation
INTRODUCTION

Competition has become increasingly fierce throughout the world, leading firms to engage in various types of strategic actions (Chen, 1996). Firms act aggressively to defeat rivals in pursuit of market gains while simultaneously adopting defensive tactics to reduce the possibility that their rivals will exploit their vulnerabilities (Porter, 1980, 1985). Therefore, in today’s business environment, a basic understanding of each subject and an integrated comprehension of both are of paramount importance. Prior research has focused on the attributes of individual actions/responses (e.g., visibility, complexity, irreversibility, and duration; Ferrier, 2001) and the aggregate effects of competitive actions (Chen and Hambrick, 1995; Miller and Chen, 1994, 1996b; Smith et al., 1991); however, scholars have neither sufficiently distinguished between offensive and defensive actions nor explored how a firm's resource portfolios and innovation strategies affect the outcomes of competitive actions.

To understand how competitive moves are associated with distinct performance outcomes, we use a contingency perspective and argue that the effects of actions on performance are contingent upon endogenous factors (a firm’s technological diversity and innovation strategy) and exogenous factors (the network structure). A firm’s competitive actions are constrained by its resources (Sirmon, Hitt, and Ireland, 2007). Without divergent resources, firms are prevented from or will be inefficient at initiating competitive actions (Chen, 1996; Lamberg et al., 2009; Ndofor, Sirmon, and He, 2011). Previous studies have stressed the importance of firm resources in providing the foundation of competitive advantage (Barney, 1991); nonetheless, scholarly research has not sufficiently examined how the variety in a firm's resource portfolio affects the impact of its competitive initiatives and vulnerability on firm performance (Priem and Butler, 2001; Smith et al., 2001). This study aims to address this gap by examining the moderating role
of technological diversity in the competitive actions–performance link.

Enhanced rivalries and rapid technological changes have undermined the sustainability of competitive advantage (Bettis and Hitt, 1995; D'aveni, 1994; Thomas, 1996). Firms not only develop resources internally but also leverage broadly distributed technologies from external organizations to facilitate innovation and to bring new ideas quickly to market, thereby avoiding lock-ins during races (Mowery, Oxley, and Silverman, 1998; Powell, Koput, and Smith-Doerr, 1996; Tsai and Wang, 2008; Vanhaverbeke, Duysters, and Noorderhaven, 2002). In particular, for high–tech firms, in–house R&D is not the only possible resource for technical know–how confronting broad and rapid changes in their core technologies (Brahm, 1995; Perrow, 1967). Decisions to ‘keep or sell’ or ‘make or buy’ R&D resources have thus become particularly relevant and critical (Nambisan and Sawhney, 2007). However, the dearth of studies investigating moderating effects on the action–performance relationship constitutes an important research gap. This paper represents an initial attempt at applying the perspective of an open innovation strategy to competitive strategy research to analyze how firms effectively utilize inbound and outbound open innovation to strengthen the effectiveness of their strategic actions.

A firm’s strategic actions are embedded in and constrained by its social structure (Burt, 1992; Fombrun, 1982; Granovetter, 1985). Crowding in terms of the level of structural equivalence between members in a network of resource flows will affect a firm's survival (Podolny, Stuart, and Hannan, 1996); for managers, it is important to understand the conditions that allow firms to make competitive moves and to employ successful defensive strategies. Drawing on social network theory, we use the concept of technological crowding, which is employed by Stuart (1998), to explore under what conditions strategic actions provide performance benefits to a firm.
This paper makes several contributions to the literature. First, it contributes to competitive dynamic research by identifying—in a fine-grained manner—a firm's competitive actions as engaging in competitive initiatives and protecting competitive vulnerabilities (Chen, 1996; Porter, 1980). Specifically, this paper provides a more refined understanding of how firms compete by examining the moderating effects of endogenous and exogenous factors on the action–performance linkage. Second, by linking the resource–based view and the competitive dynamics literature, this study accentuates the moderating role of technological diversity. A firm’s strategic actions are constrained by its resources (Teece, Pisano, and Shuen, 1997); specifically, firms with divergent resources are likely to have a wider range of competitive action portfolios to initiate (Chen, 1996; Miller and Chen, 1996a; Miller and Chen, 1996b). We argue that technological diversity plays a moderator role that firms can leverage to achieve superior performance via strategic actions. Third, our work is the first attempt to integrate the view of open innovation into competitive strategy research by emphasizing how firms engage in both inbound and outbound open innovation strategies to enhance firm performance via competitive initiatives and to mitigate the risk of vulnerabilities associated with rivals’ attacks. Finally, another important contribution of this work is that it examines strategic actions under the context of social structure by integrating network theory (which has focused primarily on structural attributes) with theories regarding a firm’s strategic behaviors.

The remainder of this article is organized as follows. First, we review the basic concepts underlying our theoretical arguments. Second, we develop hypotheses for empirical testing. Then, we present the details of our data sources and the results. Finally, we conclude the paper with a discussion of the findings, emphasizing both our contributions and the study’s limitations.

CONCEPTUAL BACKGROUND
The importance of competitive initiatives has been widely acknowledged via such concepts as the first-mover advantage (Lieberman and Montgomery, 1988) and strategic initiative (MacMillan, 1982, 1988). Undergirding such theories is the notion that under uncertainty, firms count on the success of competitive attacks to secure sustainable benefits (Wernerfelt and Karnani, 1987). While firms capture and maintain the initiative, their rivals are forced to take a reactive role rather than a proactive one (MacMillan, 1982). Several types of competitive advantage—such as building a reputation as a pioneer or leader, defining the standards for technology or other activities, enjoying the benefits of institutional barriers against imitation, and earning above-average returns (Porter, 1985)—can accrue to firms that actively pursue initiatives, which further empowers them to challenge inactive firms (Boyd and Bresser, 2008; Chen and MacMillan, 1992; Ferrier, Smith, and Grimm, 1999). Research has further shown that several factors, including a firm’s size (Chen and Hambrick, 1995), information processing capacity (Smith et al., 1991), market growth (Miller and Chen, 1994), past performance (Ferrier et al., 2002), and TMT characteristics (Hambrick, Cho, and Chen, 1996), in addition to its rivals' potential responses (Chen and MacMillan, 1992; Smith, Grimm, and Gannon, 1992), affect the likelihood of a firm initiating a competitive attack.

While firms engage in competitive battles and initiate attacks to improve their competitive position, they also must adopt defensive strategies to fend off or reduce the risk of rivals' challenges (MacMillan, 1982; Porter, 1980). As Porter (1985) noted, “The most successful competitive strategies combine offensive and defensive components”. A firm uses a defensive strategy to defend its reputation, to signal toughness, to avoid further attacks, to retain its market share, and to protect its position (Clark and Montgomery, 1998; Fombrun and Shanley, 1990; Weigelt and Camerer, 1988). Studies of competitive dynamics have shown that the propensity of
a defender to react is based on the type of action (Chen, Smith, and Grimm, 1992), its
dependence on the market being attacked, action irreversibility (Chen and MacMillan, 1992),
resource similarity (Chen, 1996), the actor's reputation (Hanson et al., 2001), and resource
availability (Meyer, 1982; Smith et al., 1991). If an attack has already begun, a defending firm
must decide how to react to lower its potential harm (Porter, 1985). Research has shown that a
firm's competitive actions matter in terms of performance (Chen and Miller, 1994; Young, Smith,
and Grimm, 1996). Competitive dynamics scholars have found that attributes such as the speed,
scope, and type of actions impact firm performance (Chen and MacMillan, 1992; Chen et al.,
1992); however, very little research has investigated the full picture of how a firm effectively
initiates a move and reduces the erosion of rivals' threats to enhance its performance (Chen and
Miller, 2012). Our study addresses this gap by examining endogenous factors (a firm's
innovation strategies and technology diversity) and exogenous factors (a firm’s network
structure) that influence the linkage between competitive strategies and performance.

**Competitive actions over resources**

Scholars have investigated various aspects of competitive actions (Caves and Porter, 1977;
Chen and MacMillan, 1992; Ferrier et al., 1999; Porter, 1979, 1980; Schumpeter, 1934; Young et
al., 1996); however, the focus of this study will differ from most of the earlier competition
literature. This study aims to investigate a firm’s resource-based competitive actions, as opposed
to its market-oriented activities—such as advertising, pricing, and new product introductions—
which are the typical foci of most studies (Chen, Lin, and Michel, 2010; Chen et al., 1992; Yu,
Subramaniam, and Cannella, 2009). The vast majority of the competition literature has regarded
resources as a supporting factor that firms use to sustain their competitive advantage (Barney,
1991; Conner, 1991; Peteraf, 1993), to predict competitive behavior (Chen, 1996; Chen and
MacMillan, 1992), to perceive competitive tension (Chen, Su, and Tsai, 2007) and competitor acumen (Tsai, Su, and Chen, 2011), and/or to influence their responses to rivals' attacks (Chen, 1996; Yu and Cannella, 2007; Yu et al., 2009) in competitive activities. However, resources should be considered axes of competition and a firm's strategic weapons rather than as having marginal roles in support of its competitive actions in the product marketplace (Markman, Gianiodis, and Buchholtz, 2009). Patents are important technological resources, particularly for high–tech firms that rely heavily on intellectual property rights for their competitive advantage (Rivette and Kline, 2000). “Patent portfolio races” among firms have become more intensive and have noticeably increased over the past two decades (Hall and Ziedonis, 2001), and patent litigation has been the primary approach by which firms have declared their commitment to fend off competitors (Clarkson and Toh, 2010). Unfortunately, there has been no systematic investigation of how firms attack and defend such strategic moves, and there has not been an assessment of the reliability and validity of this type of strategic action. The lack of attention to attacking and defending strategies has created a potentially significant knowledge gap for researchers, particularly for those who study competitive strategies. This study addresses this gap by systematically exploring firms’ competitive actions over resources.

**HYPOTHESES**

**Competitive initiatives and firm performance**

Scholars have shown that a firm's competitive initiatives matter in terms of its performance (Chen and Hambrick, 1995). A firm that undertakes a greater number of competitive initiatives will achieve higher performance for several theoretical reasons. First, pursuant to the action–derived learning effect, when a firm is aggressively initiating actions, it not only creates internal assets in the form of skills, routines, and knowledge regarding how to conduct actions but also
enhances cross-boundary assets, such as contracts, brand reputation, and networks (Nelson and Winter, 1982). Maintaining or enriching such strategic assets requires continuously undertaking competitive actions, which generates learning effects based on the efficient execution of such actions. Based on the learning perspective, the cost of taking action will be lower for a firm that has efficiencies deriving from the rich experience of prior actions; therefore, firms with an abundant history of action-derived learning effects will have both lower costs of supporting superior performance and the ability to undertake more actions over a given period. Thus, the more competitive initiatives a firm has engaged in, the better the firm will be at avoiding market erosion (Ferrier et al., 1999) and the better its performance will be over time (Young et al., 1996).

Second, firms that take more competitive initiatives can seize a series of temporary advantages over rivals in a hypercompetitive environment (D'aveni, 1994). In an era of hypercompetition, a firm must take actions to create a series of temporary advantages that will disrupt rivals’ market positions. A firm that aggressively engages in more competitive actions can exploit more opportunities and eliminate the potential for rivals to retaliate, thus enhancing its own performance (Chen and MacMillan, 1992; Kirzner, 1997; Schumpeter, 1934).

Third, a firm’s aggressive behavior serves as a signal that deters rivals' future moves. Scholars of game theory and signaling perspective argue that a firm’s intensive and aggressive actions serve as signals that shape a predatory reputation or one for toughness (Kreps and Wilson, 1982; Milgrom and Roberts, 1982). Aggressively taking competitive initiatives leads market participants and rivals to conclude that the firm will vigorously defend its competitive position in the future. Therefore, an aggressive firm will build a reputation as a “tough competitor”, deterring the sequential actions of rivals and subsequently earning rents as a result
In summary, the theoretical perspectives outlined above support the notion that superior performance is associated with firms that exhibit more competitive initiatives. Therefore, we propose the following hypothesis:

**Hypothesis 1: Competitive initiatives are positively related to firm performance.**

**Vulnerability and firm performance**

Srivastava, Shervani, and Fahey (1997) found that the actions of various competitive entities inevitably generate and/or expose vulnerabilities and negatively affect a firm’s sales growth and/or cost patterns. We define vulnerabilities using the number of unique patent lawsuits brought against a firm in a given year. Given the ownership rights and legal protections associated with them, patents help firms not only to legally produce or sell products but also to safeguard themselves against unauthorized use of their proprietary knowledge by imitators and rivals (Hall and Ziedonis, 2001). Three primary mechanisms for the negative relationship between vulnerability and firm performance are suggested in the literature. First, vulnerability will damage the reputation of the defendant (Field, Lowry, and Shu, 2005). Corporate reputations have long been regarded as strategic assets. Previous empirical research has confirmed the beneficial impact of building a positive reputation—or brand capital—based on firm performance (Rao, 1994; Roberts and Dowling, 2002). However, by being sued for violating regulations or infringing the rights secured by a competitor’s patent, firms will suffer reputation loss (Williams and Barrett, 2000), which will negatively affect firm performance (Karpoff and Lott, 1993, 1999; Koku and Qureshi, 2006).

Second, vulnerability distracts management. Once a lawsuit is filed, the two parties enter the discovery process, which requires the alleged infringer to provide extensive documents. This
process distracts, delays, imposes additional costs and forces managers to divert time from more productive efforts, resulting in a loss of market share (Koku and Qureshi, 2006). Patent infringement litigation substantially misallocates defendants’ resources, absorbing the time, energy, and attention of company managers, lawyers, engineers, and scientists (Somaya, 2003), resulting in an average loss of market value of 3.1 percent (Lerner, 1995).

Third, vulnerability to legal actions is associated with sizable expenditures. In cases in which more than $25 million is at risk, median litigation costs for a trial can reach $5 million for each side, excluding damages and royalties (AIPLA, 2011). Such expenses lead defendants, particularly thinly capitalized firms, to suffer increasingly negative stock price reactions and negative performance (Bhagat, Brickley, and Coles, 1994). If the defendant lacks sufficient strategic stakes or resources to defend or counterattack, it runs the risk of losing its reputation of being willing to fight for its key markets, thereby encouraging further attacks from both the original attacker and others (Chen and MacMillan, 1992). In summary, as the number and intensity of attacks increases, firm performance is likely to suffer (Smith et al., 1991). Accordingly, we hypothesize as follows:

*Hypothesis 2: Vulnerability is negatively related to firm performance.*

**The moderating effect of technological diversity**

Technological diversity is defined as the breadth or scope of a firm’s knowledge related to technological advancement (Granstrand, Patel, and Pavitt, 1997; Lin, Chen, and Wu, 2006; Ndofor et al., 2011; Patel and Pavitt, 1997). A firm can be conceived of as a portfolio of unique resources (Barney, 1986, 1991; Miller, 2003; Teece et al., 1997; Wernerfelt, 1984). Resources alone do not generate performance but instead form the potential that strategic actions help realize (Sirmon et al., 2007). The theoretical discussion on the impact of competitive actions on
firm performance thus must incorporate resource conditions as a contingent factor in the relationship. For any high-technology firm, technological resources are important not only to financial performance but also to firm viability to respond to either market signals or rivals’ actions (Malerba and Marengo, 1995; Miller, 2006).

Firms can choose the scope and breadth of technological resources that they pursue. Previous studies argue that de-diversification can be a competitive tool because it entails numerous economies and allows a firm to focus on a narrow technological field in which it can perform at its best (Comment and Jarrell, 1995). However, in turbulent and rapidly changing industrial sectors, such as the communications and semiconductor industries, de-diversification can lead to risk and problems. Concentrating on a few technologies or strategic repertoires will leave gaps that ignore key contingencies, challenges or opportunities (Stacey, 1992). Dynamic competition encourages firms to pursue lines of research distinguished from those of rivals and to explore new combinations of knowledge (March and Simon, 1958; Schumpeter, 1947). Moreover, without divergent technological resources, firms are prohibited from or will at least be ineffective at initiating competitive actions (Chen, 1996; Lamberg et al., 2009; Ndofor et al., 2011). Firms that develop a broad set of technological resources will be perceived as more capable and—perhaps—less predictable. More specifically, firms that develop wider technological bases are able not only to gain synergy for their core business (Granstrand et al., 1997; Patel and Pavitt, 1997) but also to obtain greater bargaining power and stronger positions of competition by deploying highly diverse resources (Gambardella and Torrisi, 1998; Markman et al., 2009; Singh et al., 2001; Tanriverdi and Venkatraman, 2005).

By varying their technological assets, firms can exploit a variety of ‘technological opportunities’ in the relevant domain and pursue unique combinations of knowledge (Jaffe, 1986;
Miller, 2006; Scherer, 1965). In particular, winners of technology contests can obtain the majority of the market share and extend their design to other product categories, thereby creating synergy. The competitive behaviors of winners and the advantages of winner-take-all competitions seriously threaten the survival of a firm’s rivals (Wärneryd, 2002). Furthermore, acquiring and developing various types of technology allow a firm to undertake effective competitive actions and to produce a predatory reputation that fends off its rivals (Bowen and Wiersema, 2005). As the competitive dynamics perspective suggests, for firms facing competitive and turbulent environments, a narrow range of resources may limit their ability to initiate actions or to respond to sudden change (Stacey, 1992). Greater breadth in technological resources allows firms to find more idiosyncratic combinations of resources to support a greater variety of actions against rivals' attacks; such a firm thereby benefits more by taking aggressive actions or by mitigating the negative effects of vulnerability on performance (Miller and Chen, 1996a; Miller and Chen, 1996b; Ndofor et al., 2011). Therefore, based on the above discussion, we propose the following hypotheses:

**Hypothesis 3a:** Technological diversity positively moderates the relationship between competitive initiatives and firm performance.

**Hypothesis 3b:** Technological diversity positively moderates the relationship between vulnerability and firm performance.

**The moderating effects of inbound and outbound open innovation strategies**

Although in–house R&D has traditionally been a critical source of technical knowledge for firms, it is not the only possible source (Mowery et al., 1998). Chesbrough and Crowther (2006) define two types of open innovation strategies in which firms engage: inbound open innovation and outbound open innovation. Inbound open innovation is the inward transfer of technology
through the exclusive commercialization of technological knowledge or its application to a firm’s products (Lichtenthaler, 2005; Spithoven, Clarysse, and Knockaert, 2010). Outbound open innovation is the outward technology transfer by searching for external organizations that are better suited to commercialize a firm’s exclusively held technology or to incorporate these technologies into their own in-house applications (Lichtenthaler, 2009).

Firms that are attacked or sued by their rivals in a patent litigation frequently encounter greater challenges in terms of resource shortages. These firms’ lack of a fully developed intellectual property portfolio renders commercialization of their products difficult and results in greater vulnerability to legal assaults. Therefore, acquiring strategic patents and assets from external organizations will strengthen a firm’s patent portfolio, securing its ability to continue to commercialize its products, and mitigate competitive threats from its rivals, thus making it easier to better defend its products from legal actions. In particular, regarding firms developing rapidly changing technologies, building larger portfolios of patents may reduce the hold-up threats posed by rivals and thus enable these firms to negotiate access to external technologies on more favorable terms (Hall and Ziedonis, 2001). Inbound open innovation strategy enables firms to acquire broadly distributed technologies to avoid lock-ins, to gain a preemptive advantage or limit a competitor’s first-mover advantage (Benassi and Di Minin, 2009; DeLorme, 1998; Tsai and Wang, 2008), to reduce the room available to competitors to maneuver in developing their own technologies (Benassi and Di Minin, 2009; Svensson, 2007), to improve their financial performance (Kafouros and Forsans, 2012), and to maintain ownership of a bundle of resources to minimize the threat of legal assaults. Therefore, we suggest that an inbound open innovation strategy helps strengthen the positive effects of competitive initiatives on firm performance and mitigates the negative effects of vulnerability on firm performance.
Conversely, outbound open innovation strategy involves substantial risk because it may weaken a firm’s competitive position by transferring its relevant knowledge (Arora, Fosfuri, and Gambardella, 2001). Studies in the Austrian school suggest that as a firm’s cumulative competitive actions increase, it creates not only internal assets in the form of skills, routines, and knowledge regarding how to conduct actions but also cross-boundary assets, such as contracts, brand reputation, and networks (D’aveni, 1994; Nelson and Winter, 1982; Young et al., 1996). This abundant asset base triggers internal learning effects, enabling firms to secure business opportunities and first-mover advantages (Schumpeter, 1950). Outbound open innovation, however, diminishes the strategic benefits of competitive initiatives. Although outbound open innovation generates monetary and strategic benefits (Lichtenthaler, 2009), it does not compensate for the negative effects of a weaker competitive position resulting from the sale of unique corporate assets (Fosfuri, 2006). Many firms are reluctant to use outbound patent strategies because of the increased risk of proprietary knowledge leakage and involuntary spillovers. Of particular importance in this regard is the profit-dissipation effect, which lowers profits when knowledge and intellectual property are revealed to external partners that may eventually become competitors (Fosfuri, 2006; OECD, 2008). In addition, hazards involving knowledge appropriation occur when firms share critical knowledge with others who can appropriate knowledge without payment or with below-value payments (Nickerson and Zenger, 2004). Therefore, based on the above discussion, we propose the following hypotheses:

**Hypothesis 4a:** Inbound open innovation positively moderates the relationship between competitive initiatives and firm performance.

**Hypothesis 4b:** Inbound open innovation positively moderates the relationship between vulnerability and firm performance.
Hypothesis 4c: Outbound open innovation negatively moderates the relationship between competitive initiatives and firm performance.

The moderating effects of technological crowding

Technological crowding is the extent to which a firm specializes in areas of technology that are densely populated by other firms (Stuart, 1999; Stuart and Podolny, 1996). Firms occupy a crowded technological position when many other firms are simultaneously pursuing the same areas of technological specialty; therefore, technological crowding is much like an organization-specific measure of overlap density—reflecting the degree to which the technological focus of a firm is shared by many other firms—and is also regarded as an important dimension of a firm’s competitive environment (Baum and Singh, 1994; Podolny et al., 1996; Stuart, 1998). Increased technological crowding implies greater competition for resources in the population and a higher likelihood of mortality (Baum and Singh, 1994).

The network literature identifies crowding as a basis for competition that closely corresponds to the concept of structural equivalence. For example, Burt (1992) used structural equivalence to define the competitive intensity between actors. Podolny et al. (1996) linked the concept of structural equivalence to niche overlap by using the overlap of patent citations as a measure of technological crowding and argued that semiconductor firms with many structurally equivalent competitors in a network (as measured by patented technologies) experienced lower rates of growth. A crowded area in the technological network is characterized by high levels of niche overlap, greater resource similarity, and greater structural equivalence.

A key feature of rivalry is its dynamic and iterative nature; scholars argue that a rival's potential response is a matter of great concern to a firm (Weigelt and MacMillan, 1988). A firm will view an attack as highly threatening when it is initiated by a rival with high resource
similarity, which increases the possibility of retaliation and the possibility that the firm might lose its monopoly status and that it might not secure the benefits conferred by actions (Chen and MacMillan, 1992; MacMillan, McCaffery, and Van Wijk, 1985; Mansfield, 1968; Porter, 1980). Therefore, a focal firm might benefit less from initiating competitive actions and suffer more from rivals' attacks when it is situated in a heavily populated area of technology. Based on the above discussion, we propose the following hypotheses:

_Hypothesis 5a: Technological crowding negatively moderates the relationship between competitive initiatives and firm performance._

_Hypothesis 5b: Technological crowding negatively moderates the relationship between vulnerability and firm performance._

**METHODOLOGY**

**Sample and data collection**

We tested our hypotheses in the context of the U.S. communications equipment industry (Standard Industrial Classification [SIC] codes 366 and 367) from 1989 to 2008. We choose this industry primarily because it is subject to extremely intensive patent infringement competition, and a firm’s ability to develop new technologies and its R&D efforts in this industry have a great impact on its performance in this setting (Clarkson and Toh, 2010). A five-stage process was adopted to determine the final sample. First, using the COMPUSTAT database and the three-digit SIC codes 366 and 367, we identified all publicly traded firms in the communications equipment industry. We then tracked the parents of these firms via the Securities Data Corporation (SDC) database, and in situations entailing subsidiaries, we focused on the parent firms because they own, address, and oversee IP litigation. This process resulted in a panel of 425 firms.

Second, we excluded 75 companies that did not have complete financial records for at least
10 years in the COMPUSTAT database. Third, a patent infringement lawsuit is registered and becomes part of the public record once it is filed in the United States Federal District Court. We obtained patent infringement records from the Westlaw (LitAlert) database, which contains complete records of patent litigation cases in the United States and provides the associated patent numbers, filing dates and docket numbers of the lawsuits and the identities of plaintiffs and defendants. To ensure the accuracy and completeness of patent infringements, we also verified and triangulated the Westlaw database records with Lexis-Nexis Law records.

Fourth, following established methodologies, we matched our data with patent records from the United State Patent and Trademark Office (USPTO) and the National Bureau of Economic Research (NBER) patent database (Hall, Jaffe, and Trajtenberg, 2001). Finally, we removed 133 firms that had no patents or were not involved in patent infringement lawsuits from 1989 to 2008, yielding a sample of 184 firms. After a list–wise deletion of observations with missing data, the effective sample for analysis contained 1,674 firm–year observations. To facilitate causal inferences, we adopted a one–year lagged dependent variable model to examine the relationships among independent variables.

**Firm performance**

This study used market share to measure firm performance. Market share (defined as the firm’s dollar amount of sales divided by the total sales of all firms active in each of the four-digit industries) has long been identified as one of the most important indicators of firm performance (Tanriverdi and Lee, 2008; Venkatraman and Ramanujam, 1986), particularly in investigating the performance implications of firms’ strategic moves (Chen and MacMillan, 1992). Data were accessed from the COMPUSTAT database. We introduced a one–year lag into the performance measure to assess how the independent variables and controls in year $t$ impacted firm
performance in year $t+1$.

**Competitive initiatives and vulnerability**

This study relied on patent litigation data because patents are valuable, rare, inimitable and non-substitutable resources that firms create (Markman, Espina, and Phan, 2004), and patents also represent formidable barriers to entry and imitation (Somaya, 2003). Unlike price cuts and other imprecise measures of competitive attacks, instances of patent litigation are more reliable proxies of hostility over resources; lawsuits provide “unambiguous depictions of who attacks whom, where, when, and over what issue” (Lanjouw and Schankerman, 2001; Markman et al., 2009:426; Polidoro and Toh, 2011). Patents are powerful barriers because they exclude others from accessing technological corridors (as delineated by patent “claims”); thus, this research uses patent litigations as a proxy for the competitive initiatives of firms (Somaya, 2012). This framing is consistent with earlier work that defines competitive initiatives as competitive attacks challenging rivals (Agarwal and Helfat, 2009; Ferrier, 2001; Lumpkin and Dess, 1996, 2001).

For each firm in the sample, we counted the number of unique instances of patent litigation that a firm initiated in a given year. In short, competitive initiative involves the number of times in which a firm, as a plaintiff, brought legal action related to patent litigation (D'aveni, 1994; Ferrier et al., 1999; Young et al., 1996). Vulnerability is measured as the number of unique instances of litigation in which a firm was accused of patent infringement in a given year.

**Moderating variables**

**Inbound and outbound open innovation**

This paper used the USPTO patent assignments database to measure inbound and outbound open innovation. According to United States patent law, an assignment is defined as a written document recorded at the USPTO to publicly acknowledge its new owner. To assign a patent, the
The assignor (seller) and assignee (buyer) must complete a special form (PTO1595) or use the Electronic Patent Assignment System (EPAS) via the Internet to register the assignment with the USPTO. Once the transaction is completed and recorded at the USPTO, the assignee becomes the owner of the patent. Transferring ownership in patent transactions captures the nature of two types of open innovation. Hence, we measured inbound open innovation as the number of patents a firm purchases and outbound open innovation as the number of patents a firm sells in a given year. We gathered data about patent assignments that were announced and assigned between 1989 and 2008.

**Technological diversity**

A firm's patent portfolio provides an indication of the extent of its inventiveness and the level of innovation, which effectively represents its technological knowledge (Hall et al., 2001). Therefore, the breadth of a firm's patent portfolio is utilized as the indicator of the breadth of its technological resources (Miller, 2004). In addition, as Miller (2004) noted, patents do not "reveal all valuable knowledge of the firm, but that the breadth of knowledge represented by patents is an accurate indicator of the breadth of the firm's technological resources" (p. 1118). Following the previous literature (Hall et al., 2001; Lin et al., 2006; Miller, 2004; Ndofor et al., 2011), we measured technological diversity as the number of patents in a firm’s patent portfolio belonging to six technology categories \(X_i, i=1\) to 6) defined by the NBER patent database (Chemical, Computer/Communication, Drug/Medical, Electrical/Electronic, Mechanical, and Others). The formula follows below. Previous studies examining the relationship between strategies and performance have typically used measures that were five-year averages (Lin et al., 2006); accordingly, we set the observation period to five years.
Technological crowding

Technological crowding of a firm is measured by aggregating the ratio of common patent citations made by dyad firms and the total number of patent citations made by the focal firm, which reflects the degree to which the technological focus of a focal firm is shared by many other organizations (Stuart, 1998; Stuart and Podolny, 1996). Accordingly, we use $C_{ijt}$ to denote the degree to which a firm $j$ crowds the position of a focal firm $i$ during period $t$, and we define dyadic technological overlap as follows:

$$C_{ijt} = \frac{\sum_p C_{ipt} C_{jpt}}{\sum_p C_{ipt}} \quad \text{where } i \neq j$$

where $p$ indexes all existing patents and $C_{ipt}$ and $C_{jpt}$ are coded 1 if the patents of firms $i$ and $j$ cite patent $p$ at time $t$ and 0 otherwise. Therefore, summing over $p$, $C_{ipt} C_{jpt}$ increases when the patents of firms $i$ and $j$ cite a common patent, and the denominator is the total number of patent citations made by firm $i$’s patent portfolio. In essence, each organization $j$ contributes to organization $i$’s crowding index the proportion of $i$’s patent citation that is also made by $j$ during $t$. To move from the level of a dyadic overlap to a composite crowding score for firm $i$, we summed the dyadic overlap scores across $j$. Formally,

$$A_{it} = \sum_j C_{ijt} \quad \text{where } i \neq j$$

Following the previous literature (Stuart, 1998; Stuart and Podolny, 1996), we used a five-
year moving window to compute the crowding index. The technological overlap coefficients and the composite crowding scores were computed using all patent activity during the previous five years, t-5 to t-1.

**Control variables**

Consistent with strategy research in this area and with the effort to exclude alternative explanations, this study included the following control variables: firm age, firm size, R&D intensity, past performance, slack resources, and alliances. We operationalized firm age, which may account for its experience and clout, as the number of years since a firm’s founding. Given that larger firms may have greater resources and therefore a higher propensity to initiate actions than smaller firms (Barnett and McKendrick, 2004), we controlled for firm size, which we measured as the natural logarithm of the total assets of firm $i$ in year $t$. Firms that invest heavily in R&D are more likely to compete on the basis of their technology (O'Brien, 2003); therefore, this study controlled for a firm’s R&D intensity, as measured by the ratio of a firm’s annual R&D expenditures to its total assets (Wang, He, and Mahoney, 2009). Superior past performance reduces a firm’s motivation to compete aggressively (Ferrier, 2001; Miller and Chen, 1994); therefore, we added a past performance measure, parameterized by a firm’s sales growth for the prior year (Carroll and Hannan, 2004). Given that greater slack resources augment a firm’s competitive repertoire—including its competitive initiatives (Chen and Miller, 2012)—we controlled for two types of slack resources. Absorbed slack (the slack that is absorbed by costs) is measured as selling, general, and administrative expenses divided by total revenue. Unabsorbed slack (uncommitted liquid resources) is measured as the ratio of current assets less inventory to current liabilities (Singh, 1986; Smith et al., 1991). Further, alliances are cooperative efforts that often mitigate competitive intensity (Silverman and Baum, 2002). To
account for such influence, we included the number of alliances established by a focal firm.

RESULTS

Table 1, which presents the means, standard deviations, and correlations for all variables used in the analyses, suggests that there are no critically collinear variables in the data (e.g., r > 0.8 (Kennedy, 2003)). Table 2 presents the hierarchical regression results used to examine Hypotheses 1–5. Model 1 represents the base model, which includes only control variables. Model 2 introduces two independent variables: competitive initiatives and vulnerability. Models 3–4 include four moderating variables—technological diversity, inbound open innovation, outbound open innovation, and technological crowding—and then incorporates their interaction effects. Model 5 includes all the interaction terms. To address potential issues involving multicollinearity, we calculated the variance inflation factors (VIFs) for all the predictors in the model. All VIFs associated with each predictor are within the range of 1.05 to 2.37, with a mean of 1.47. These results are well within acceptable limits, suggesting that multicollinearity is not a concern (Hair et al., 1998).

Insert Table 1 and Table 2 About Here

Model 2 tests Hypothesis 1 and Hypothesis 2. Hypothesis 1 proposed that a firm’s competitive initiatives will positively affect its performance. Model 2 shows that the coefficient for competitive initiatives is positive and statistically significant \(b=0.024; p<0.05\), supporting Hypothesis 1. Hypothesis 2 predicted that a firm’s vulnerability will negatively affect its performance. The coefficient of vulnerability is negative and marginally significant \(b=-0.033; p<0.1\). Therefore, Hypothesis 2 is also supported. Hypothesis 3a predicted a positive moderating influence of technological diversity on the effectiveness of competitive initiatives. In model 3, the interaction between competitive initiatives and technological diversity is positive and
statistically significant \((b=0.106; p<0.05)\), indicating that the positive impact of competitive initiatives on performance is even stronger with greater technological diversity. Thus, Hypothesis 3a is supported. Model 4 shows that technological diversity has a positive yet insignificant influence on vulnerability–performance relations; therefore, Hypothesis 3b is not supported.

Hypothesis 4a posits that inbound open innovation will strengthen the impact of competitive initiatives on firm performance. The positive and significant coefficient for the interaction between competitive initiatives and performance (Model 3; \(b=0.027; p<0.01\)) provides strong support for Hypothesis 4a. Hypothesis 4b proposes that inbound open innovation will mitigate the negative impact of vulnerability on performance. The coefficient for the interaction between vulnerability and inbound open innovation on performance is positive and statistically significant (Model 4; \(b=0.073; p<0.001\)), supporting Hypothesis 4b. Hypothesis 4c predicts a negative moderating effect of outbound open innovation on competitive initiative-performance relations. The interaction term in model 3 reveals that this effect is negative and significant \((b=-0.014; p<0.05)\), supporting Hypothesis 4c.

Hypothesis 5a posits that technological crowding will weaken the positive impact of competitive initiatives on firm performance. The coefficient for the interaction between competitive initiatives and technological crowding on performance is negative and statistically significant (Model 3; \(b=-0.017; p<0.001\)), supporting Hypothesis 5a. In other words, a focal firm would benefit less from initiating attacks concentrating on a heavily populated area of technology; the less the technological focus of a firm is shared by many other firms, the stronger the positive influence of its competitive initiatives on performance. Consistent with our prediction in Hypothesis 5b, technological crowding has a significant negative effect (Model 4; \(b=-0.013; p<0.05\)) on vulnerability–performance relations, implying that rivals' challenges are more threatening when firms are located in a heavily crowded area of technology.
DISCUSSION AND CONCLUSION

Anchored in the competitive dynamics perspective, this study presents a conceptual model for examining the relationship between firms' competitive behaviors (including competitive initiatives and vulnerabilities) and financial performance in different settings. In examining the role of open innovation, technological crowding, and technological diversity in the relationship between competitive behaviors and firm performance, this study has several implications. First, this paper contributes to competitive dynamic literature by answering the need for research to distinguish firms’ competitive initiatives from defenses against vulnerabilities, with such distinctions having different and important influences on firm performance (Chen et al., 2010). We found the direct positive effect of competitive initiatives on firm performance and the negative effect of vulnerability on firm performance. The present evidence implies that a firm that tends to act frequently in the resource marketplace is likely to capture business opportunities and secure advantages.

Second, this study contributes to integrate open innovation perspective into competitive strategy research by highlighting the role of open innovation strategy for firms in achieving superior performance. We found that inbound open innovation mitigates the negative effects of vulnerability on firm performance and that outbound open innovation diminishes the positive effects of competitive initiatives on firm performance. This finding supports the emerging view that open innovation strategies influence a firm's competitive advantage and performance (Lichtenthaler, 2015), a view that has been largely neglected in the competitive dynamics literature. Firms acquire technology from external sources to strengthen their portfolios, their bargaining power, and their competitive advantage (Gambardella and Panico, 2014), whereas outward transfer of technology may result in the risk of strengthening competitors by selling corporate “crown jewels”, i.e., competitively relevant technology (Lichtenthaler, Hoegl, and
Third, our research shows that the composition and characteristics of technology portfolio do affect corporate performance implications of competitive actions. We found that technological diversity positively moderated the relationship between competitive initiatives and firm performance, suggesting that a more divergent technology profile magnifies the value of the benefits that accrue from aggressive actions. We speculate that building a broad set of technological resources enables firms to realize the economic returns of aggressive actions by acquiring substantial bargaining power, pursuing unique combinations of knowledge across domains and reducing the risks inherent in dynamic environments (Bowen and Wiersema, 2005). In contrast, a narrow range of technological resources may limit firms' ability to undertake competitive actions, resulting in lost opportunities and negative effects on performance. However, the results of this study reveal the lack of moderating effect of technological diversity on vulnerability–performance relations. The plausible explanation is that firms with vulnerability may have difficulties in high investment of technological diversity. As Lin et al. (2006) suggested, technological diversity brings heavy costs from coordination and integration of technological knowledge across a variety of technology disciplinary frontiers. It is difficult for firms that suffer resource shortages and rivals’ threats put extra efforts on high R&D and internal governance costs.

Fourth, this study proposes that the strength of the positive effect of aggressive actions depends on the environmental moderator. The results show that high levels of technological crowding diminish the benefits of aggressive actions. A more-crowded area of the technological network implies higher levels of niche overlap, resource similarities, and response rates, which may undermine the benefits that might otherwise accrue from aggressive actions (Chen et al., 2010; Podolny et al., 1996). Therefore, the incentives for behaving aggressively are particularly
strong in less-crowded settings.

Finally, this study has certain limitations that suggest fruitful avenues for future research. First, because our empirical analysis considers the performance implications of competitive behavior based solely on the use of patent litigation to identify a firm’s competitive behavior, it may not be comprehensive. Future research can include other sources of competitive action measures to supplement such objective measures. Second, we derive our empirical results based on a sample of technology–based firms in the U.S. communications equipment industry, raising concerns about the external generalizability of these results to other industries and countries. Future research should therefore empirically test the validity of the framework and hypotheses in other industries and countries.
REFERENCES


Kafouros MI, Forsans N. 2012. The role of open innovation in emerging economies: do


Lumpkin GT, Dess GG. 2001. Linking two dimensions of entrepreneurial orientation to firm performance: the moderating role of environment and industry life cycle. *Journal of


O'Brien JP. 2003. The capital structure implications of pursuing a strategy of innovation.


Podolny JM, Stuart TE, Hannan MT. 1996. Networks, knowledge, and niches: competition in the


Studies 7(2): 25.


Tanriverdi H, Venkatraman N. 2005. Knowledge relatedness and the performance of


Thomas I, LG. 1996. The two faces of competition: Dynamic resourcefulness and the


Tsai W, Su KH, Chen MJ. 2011. Seeing through the eyes of a rival: Competitor acumen based on

Vanhaverbeke W, Duysters G, Noorderhaven N. 2002. External technology sourcing through
alliances or acquisitions: an analysis of the application-specific integrated circuits


Wang HC, He J, Mahoney JT. 2009. Firm-specific knowledge resources and competitive
advantage: the roles of economic-and relationship-based employee governance


Table 1. Means, standard deviations, and correlations

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>S.D.</th>
<th>VIF</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Market share</td>
<td>0.03</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Firm age ( ^a )</td>
<td>2.97</td>
<td>0.75</td>
<td>1.36</td>
<td>0.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>RD intensity ( ^a )</td>
<td>-2.39</td>
<td>0.80</td>
<td>1.38</td>
<td>-0.31</td>
<td>-0.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Firm size ( ^a )</td>
<td>5.57</td>
<td>1.96</td>
<td>2.37</td>
<td>0.39</td>
<td>0.33</td>
<td>-0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Past performance</td>
<td>0.14</td>
<td>0.30</td>
<td>1.05</td>
<td>-0.03</td>
<td>-0.18</td>
<td>0.11</td>
<td>-0.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Absorbed slack ( ^a )</td>
<td>0.34</td>
<td>0.24</td>
<td>1.40</td>
<td>-0.18</td>
<td>-0.23</td>
<td>0.41</td>
<td>-0.36</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Unabsorbed slack ( ^a )</td>
<td>0.31</td>
<td>0.27</td>
<td>1.15</td>
<td>0.07</td>
<td>0.07</td>
<td>0.06</td>
<td>-0.18</td>
<td>-0.07</td>
<td>0.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Alliance ( ^a )</td>
<td>0.27</td>
<td>0.56</td>
<td>1.34</td>
<td>0.35</td>
<td>0.19</td>
<td>0.05</td>
<td>0.41</td>
<td>0.03</td>
<td>-0.13</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Competitive initiative ( ^a )</td>
<td>0.09</td>
<td>0.22</td>
<td>1.80</td>
<td>0.20</td>
<td>0.24</td>
<td>-0.06</td>
<td>0.32</td>
<td>-0.03</td>
<td>-0.14</td>
<td>0.01</td>
<td>0.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Vulnerability ( ^a )</td>
<td>0.03</td>
<td>0.13</td>
<td>1.77</td>
<td>0.15</td>
<td>0.20</td>
<td>-0.03</td>
<td>0.28</td>
<td>-0.02</td>
<td>-0.08</td>
<td>0.02</td>
<td>0.29</td>
<td>0.64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Technological diversity</td>
<td>0.35</td>
<td>0.29</td>
<td>1.55</td>
<td>0.16</td>
<td>0.25</td>
<td>0.01</td>
<td>0.54</td>
<td>-0.08</td>
<td>-0.09</td>
<td>-0.04</td>
<td>0.24</td>
<td>0.19</td>
<td>0.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Inbound open innovation ( ^a )</td>
<td>0.52</td>
<td>0.88</td>
<td>1.49</td>
<td>0.16</td>
<td>0.23</td>
<td>0.02</td>
<td>0.48</td>
<td>-0.05</td>
<td>-0.12</td>
<td>0.02</td>
<td>0.23</td>
<td>0.27</td>
<td>0.22</td>
<td>0.38</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Outbound open innovation ( ^a )</td>
<td>0.31</td>
<td>0.88</td>
<td>1.35</td>
<td>0.13</td>
<td>0.31</td>
<td>0.00</td>
<td>0.34</td>
<td>-0.09</td>
<td>-0.07</td>
<td>0.05</td>
<td>0.21</td>
<td>0.24</td>
<td>0.27</td>
<td>0.29</td>
<td>0.41</td>
</tr>
<tr>
<td>14</td>
<td>Technological crowding</td>
<td>3.67</td>
<td>4.74</td>
<td>1.10</td>
<td>-0.17</td>
<td>-0.19</td>
<td>0.12</td>
<td>0.08</td>
<td>0.02</td>
<td>0.01</td>
<td>-0.04</td>
<td>0.06</td>
<td>-0.01</td>
<td>0.00</td>
<td>0.15</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Mean VIF 1.47

N=1,668, *p<0.05; **<0.01; ***p<0.001

\( ^a \) Logarithm.
Table 2: Regression results for the determinants of firm performance (lag)

<table>
<thead>
<tr>
<th>Control variables</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm age (^a)</td>
<td>0.012***</td>
<td>0.011***</td>
<td>0.007*</td>
<td>0.008**</td>
<td>0.008*</td>
</tr>
<tr>
<td>Firm size (^a)</td>
<td>0.011***</td>
<td>0.011***</td>
<td>0.014***</td>
<td>0.014***</td>
<td>0.014***</td>
</tr>
<tr>
<td>RD intensity (^a)</td>
<td>-0.032***</td>
<td>-0.032***</td>
<td>-0.029***</td>
<td>-0.029***</td>
<td>-0.030***</td>
</tr>
<tr>
<td>Past performance</td>
<td>0.010</td>
<td>0.010</td>
<td>0.008</td>
<td>0.009</td>
<td>0.008</td>
</tr>
<tr>
<td>Absorbed slack (^a)</td>
<td>0.014</td>
<td>0.015</td>
<td>0.013</td>
<td>0.014</td>
<td>0.015</td>
</tr>
<tr>
<td>Unabsorbed slack (^a)</td>
<td>0.035***</td>
<td>0.035***</td>
<td>0.037***</td>
<td>0.035***</td>
<td>0.035***</td>
</tr>
<tr>
<td>Alliance (^a)</td>
<td>0.043***</td>
<td>0.043***</td>
<td>0.041***</td>
<td>0.042***</td>
<td>0.041***</td>
</tr>
<tr>
<td>Independent variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Competitive initiative (^a)</td>
<td>0.024*</td>
<td>0.024</td>
<td>0.032**</td>
<td>0.049*</td>
<td></td>
</tr>
<tr>
<td>Vulnerability (^b)</td>
<td>-0.033+</td>
<td>-0.045*</td>
<td>-0.165**</td>
<td>-0.188**</td>
<td></td>
</tr>
<tr>
<td>Technological Diversity (TD)</td>
<td>-0.016+</td>
<td>-0.007</td>
<td>-0.017*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inbound Open innovation (IO)(^a)</td>
<td>-0.005+</td>
<td>-0.003</td>
<td>-0.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outbound Open innovation (OO)(^a)</td>
<td>-0.004</td>
<td>-0.007**</td>
<td>-0.005+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technological crowding (TC)</td>
<td>-0.002***</td>
<td>-0.003***</td>
<td>-0.002***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction term</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Competitive initiative × TD</td>
<td>0.106*</td>
<td></td>
<td>0.149**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Competitive initiative × IO</td>
<td>0.027**</td>
<td></td>
<td>-0.014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Competitive initiative × OO</td>
<td>-0.014*</td>
<td></td>
<td>-0.016*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Competitive initiative × TC</td>
<td>-0.017***</td>
<td></td>
<td>-0.017***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulnerability × TD</td>
<td></td>
<td>0.099</td>
<td>-0.015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulnerability × IO</td>
<td></td>
<td></td>
<td>0.073***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulnerability × TC</td>
<td></td>
<td></td>
<td>-0.013*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-0.169***</td>
<td>-0.168***</td>
<td>-0.149***</td>
<td>-0.151***</td>
<td>-0.151***</td>
</tr>
<tr>
<td>N</td>
<td>1668</td>
<td>1668</td>
<td>1668</td>
<td>1668</td>
<td>1668</td>
</tr>
<tr>
<td>R-sq</td>
<td>0.279</td>
<td>0.281</td>
<td>0.335</td>
<td>0.327</td>
<td>0.345</td>
</tr>
<tr>
<td>adj. R-sq</td>
<td>0.276</td>
<td>0.277</td>
<td>0.328</td>
<td>0.321</td>
<td>0.337</td>
</tr>
</tbody>
</table>

N=1,668, \(^\text{a}\)p<0.1; \(^*\)p<0.05; \(^**\)p<0.01; \(^***\)p<0.001

\(^a\)Logarithm.