

From Follower to Innovator: the Metamorphosis of Chinese SMEs

Abstract

Chinese small and medium-sized enterprises (SMEs) have shown remarkable innovation despite limited research and development (R&D) capabilities and inadequate intellectual property rights (IPR) protection. This study explores the unique factors in the Chinese environment that drive radical innovation within SMEs. By extending existing innovation theory, it demonstrates that variations in R&D capabilities, transaction costs, and IPR regimes enable Chinese firms to adopt distinct innovation strategies from developed countries. Chinese firms exploit environmental inefficiencies and IPR regimes to emulate developed market innovation models. Internal R&D and open innovation utility vary based on technological complexity. As they accumulate innovation capabilities through imitation, Chinese firms adopt a low-cost strategy to outperform their counterparts. Our longitudinal study (2008 – 2024) based on a mixed method approach reveals a strategic shift from imitation to innovation. Chinese firms develop enhanced R&D capabilities through talent policy and experiential learning based on imitation, moving from foreign market reliance to self-reliance on indigenous innovation. Open innovation ecosystems and collaborative endeavors have subsequently facilitated this transition.

Keywords: open innovation ecosystems, collaborative network, low-cost strategy, R&D, innovation capability, radical innovation, China

1. INTRODUCTION

Scholars often criticize innovation performance in China, arguing that weak intellectual property rights (IPR) protection, uncertainty, institutional voids and market imperfections lead to inhospitable environments for innovation (Li and Atuahene-Gima, 2001). However, for not well understood reasons, China has surprised the world by outperforming developed countries on its way to generating the largest intellectual property output in the world (World Intellectual Property Organization (WIPO), 2012) and by achieving significant innovations in fields such as stem-cell cloning. Whereas Chinese firms have traditionally produced low-cost imitations of goods produced in developed countries, they have recently begun to generate radical innovations (e.g., Haier in consumer electronics and Huawei in telecommunications) and to capture market share previously held by firms from developed countries (Cuervo-Cazurra & Genc, 2008; Hermelo & Vassolo, 2010; Zhao, 2006). One of the puzzles that arises in this context is why Chinese firms succeed in developing *radical* innovations, i.e., innovations that involve the development and application of unique ideas or breakthrough scientific advances (Garcia & Calantone, 2002), given that a fundamental premise in the literature is that innovation is a path-dependent process that requires significant investment in R&D. Because of the insufficiently developed R&D capabilities of Chinese firms, it can be argued that they should not demonstrate high levels of innovative performance.

Although this recent phenomenon has important theoretical implications and may change the rules of the game globally, our knowledge of the forces shaping innovation in China remains inconsistent and incomplete. Prior research acknowledges that Chinese firms have risen to prominence over the last decade (Awate, Larsen, & Mudambi, 2012; Ramamurti, 2012), but little is known about the advantages that these firms leverage when they innovate, what innovation strategies they pursue and why, what the driving forces are behind these strategies, and whether these models are different because they originate in emerging countries. Because prior innovation theory has largely been developed in the context of industrialized countries, it makes assumptions that may not be valid for China (Luo, Sun, & Wang, 2011), which indicates that current innovation theory is not fully applicable to the context of Chinese firms. One challenge therefore is to identify innovation outcomes in Chinese firms that cannot be explained by theories formulated to apply to firms in developed countries.

To illustrate the shortcomings of current innovation theory, let us consider three examples. First, whereas internal R&D for firms from developed countries is considered to be the most valuable component of their innovation strategy (Teece, 1986; Zhou & Li, 2012), many Chinese firms do not possess and cannot quickly develop strong internal R&D capabilities (Guillen & Garcia-Canal, 2009; Peng, 2012). Second, whereas extant theory rests on the assumption that the legal system enables firms to limit imitation and opportunistic behavior by competitors, Chinese firms operate in institutional environments that are ineffective at enforcing IP laws and in fact encourage knowledge diffusion and imitation (Keupp, Friesike, & von Zedtwitz, 2012). Third, prior innovation theory has been influenced not only by the experiences in developed countries but also by studies of mature firms that typically innovate for over half a century (Ramamurti, 2012). Chinese firms, however, are at early developmental and innovation stages and only rarely are self-sufficient. Therefore, although they innovate in a different environment and their innovation strategy is particularly dependent on this environment (Luo et al., 2011), we still know little about what distinguishes innovative Chinese firms from less successful Chinese firms.

We seek to enhance the scholarly understanding of this subject by examining how various factors that are idiosyncratic to Chinese firms and the Chinese institutional environment influence 1) the innovation strategies adopted by Chinese firms (i.e., *how* they innovate) and 2) the ability of these Chinese firms to develop radical product innovations (i.e., their *degree of innovativeness*). Our first contribution focuses on the role of internal R&D and open innovation – the practice of using the market to acquire expertise and knowledge and to integrate external innovation opportunities (Arora, Belenzon, & Rios, 2014; Chesbrough, 2003; Dahlander & Gann, 2010; Garriga, von Krogh, & Spaeth, 2013). Using data from one of the fastest growing provinces in China, we argue that because R&D capabilities, transaction costs and IPR regimes differ in emerging countries such as China, the role of internal R&D and open innovation also varies. In contrast to the conventional wisdom that suggests that R&D is crucial to the innovation strategy of firms in developed countries, we show that R&D has only a weak or even insignificant effect on the development of radical innovations in Chinese firms. Indeed, some firms develop radical innovations without investing in formal R&D at all. However, a completely different pattern emerges when we consider the indirect effects of R&D, which indicates that R&D is a mechanism through which Chinese firms build the functional and architectural capabilities necessary to develop radical innovations using the market and open innovation. Our analysis extends conceptualizations that regard firms as efficiency-seeking and cost-minimizing actors by explaining how Chinese firms develop radical innovations by becoming skillful combiners of components, even when they do not fully understand the internal workings of these components.

The second area to which we contribute involves technological complexity. Complexity depends on the ‘problem structure’, which refers to the nature and extent of interactions among technologies (Macher & Boerner, 2012). Whereas certain radical innovations involve high technological complexity, others do not. Although prior research has recognized that the benefits and costs of accessing the market differ when complexity is high than when it is low (Singh, 1997), prior studies have not examined how technological complexity influences the role of internal R&D and open innovation in affecting the development of radical innovations in Chinese firms. This last point is particularly salient because complex radical innovations require greater demands on capability and may therefore change the innovation strategy that Chinese firms should employ. In this study, we show that complexity influences the marginal effects of internal R&D and open innovation on Chinese firms’ degree of innovativeness in different ways. In particular, R&D is more useful when Chinese firms develop less complex radical innovations. Conversely, with a high level of complexity, open innovation is more effective at developing radical innovations. These findings extend prior research that offered useful insights into how transaction costs influence decisions affecting organizational boundaries but did not examine how technological complexity impacts the effectiveness of such decisions.

Our findings contribute to innovation theory in emerging economies and challenge the perspective that only firms with strong R&D capabilities can develop radical innovations. Although this study is not comparative in nature, the analysis helps us consider the extent to which innovation theory regarding firms in developed countries explains the rise of Chinese firms as innovators. We show that Chinese firms adopt innovation strategies that differ considerably from those of firms in developed countries. These innovation strategies rely on non-market mechanisms that decrease transaction costs, on exploiting inefficiencies in the IPR regime and on knowledge sourcing from a multitude of technology suppliers. Such strategies enable Chinese firms to shift their innovation focus away from technology and

toward functional and architectural strengths, allowing these companies to rely on external markets and on the fine slicing of the global value chain to “emulate” developed country innovation models and the vertically integrated structures of developed market firms. Our analysis advances current innovation theory that suggests that firms in developed countries internalize functions to compensate for weak institutions (Zhao, 2006) by showing that Chinese firms actually do the opposite – they exploit weak IPR regimes and informal institutions to compensate for their insufficient R&D capabilities.

2. THEORETICAL BACKGROUND

2.1 Alternative perspectives on radical innovation

The distinction between refining a current product and creating an entirely new design that significantly departs from established concepts has long been recognized in the innovation literature (Henderson & Clark, 1990). Incremental innovations introduce minor improvements to existing products, exploit the potential of established technologies and designs, and sustain or reinforce consumption patterns in existing markets. By contrast, radical innovations involve developing and applying unique ideas and concepts or state-of-the-art technological and scientific advances (Chatterji & Fabrizio, 2014; Garcia & Calantone, 2002; Zhou & Li, 2012). Regardless of whether new ideas or new scientific principles form the basis for radical innovations, these innovations have the potential to significantly alter consumption patterns in an existing market, to redefine or cause discontinuity in an industry or even to lead to the creation of an entirely new sector. To explain why some firms succeed in developing radical product innovations whereas others do not, prior research – which has focused primarily on firms in developed countries – has linked such variations to two types of considerations.

The first set of factors that may affect the radicalness of innovations are internal to the firm and include its prior knowledge, resources, routines and R&D-related capabilities (Lavie, 2006). Variations in innovation outcomes in this literature are framed in terms of how a firm’s own R&D capabilities affect the internal development of state-of-the-art innovations. A second perspective focuses on the institutional environment (Dutt et al, 2015) with particular attention paid to the cost of transacting (Williamson, 1981) and the IPR regime in a given market (Teece, 1986). This view suggests that we should not examine innovation outcomes without specifying the institutional setting within which innovation takes place. Institutions influence both transaction costs in a market (Coase, 1992; Williamson, 1981) and subsequently a firm’s incentives and abilities to develop radical innovations either internally or by engaging in open innovation. Institutions also affect a country’s IPR regime by determining how effective the legal system is at protecting innovations (Teece, 1986). A strong IPR regime provides a protective framework, discourages opportunistic behavior and improves the commitment between partners, which subsequently influences a firm’s ability to both create and protect radical innovations. These two types of consideration are distinct, but both perspectives attempt to explain variations in innovation by focusing on “failure”, i.e., either market failure or capabilities failure (White, 2000).

We rely on the following three theoretical perspectives that have been essential in explaining innovation outcomes; R&D capabilities (White, 2000), transaction costs (Coase, 1992; Williamson, 1981) and IPR regimes (Teece, 1986; Pisano and Teece, 2007). Although previous research has primarily focused on one particular theoretical lens or another, it is important to our research purposes to maintain a collective focus on these three theoretical perspectives together. First, each of these three theoretical lenses makes implicit assumptions that may not be applicable to understanding Chinese firms’ innovation outcomes. To better

explain such outcomes, we must understand precisely where there is common ground between current innovation theories and conditions in emerging countries. Second, it is important to understand how the Chinese context may affect the predictions of these perspectives with respect to advancing theory on innovation. This understanding may also help us specify why we would expect the way in which Chinese firms develop radical innovations to be different from the ways in which firms create radical innovations in developed countries.

2.2 What is different about Chinese firms?

R&D capabilities. Although developed country firms are not completely self-sufficient, they are vertically integrated across three functional innovation activities: R&D, manufacturing and marketing (White, 2000). By contrast, firms in China rely on organizationally disintegrated innovation systems in which research, development, engineering, manufacturing, marketing and distribution are located in functionally specialized organizations (White, 2000). In fact, Chinese firms only rarely possess strong R&D capabilities; i.e., they are inferior at creating novel technologies (Guillen & Garcia-Canal, 2009; Park & Luo, 2001). The fact that many Chinese firms innovate without ever investing in R&D (Guan, Yam, Tang, & Lau, 2009) thus challenges mainstream innovation theory, which recognizes the role of external knowledge and markets for technology (Leiponen and Helfat, 2010; Arora et al., 2001) but it is built on the premise that firms must continuously invest in R&D to create new capabilities (Cuervo-Cazurra & Annique Un, 2010).

This method of organizing innovation systems has implications for how Chinese firms innovate. Because they are not accustomed to vertically integrating into new functional areas, they must overcome the challenges associated with the fact that they are at an early stage of innovation. Developing R&D capabilities is a path-dependent process that requires resources and diverse skills. Time compression diseconomies do not enable Chinese firms to develop R&D capabilities quickly. Due to convex adjustment costs and diminishing returns, even if Chinese firms significantly increase their R&D spending, they will not be able to build R&D capabilities in the short run that match those of firms in developed countries that have invested in R&D for several decades.

To overcome this challenge, Chinese firms must rely on external markets. However, having limited R&D capabilities (i.e., limited abilities with respect to developing new technologies) does not equate to having limited innovation capabilities. Whereas firms in developed countries rely on creating new technology, innovation systems in emerging countries are designed to assimilate and combine foreign technologies (Keupp et al., 2012; Liu et al, 2011). China is a leading recipient of outsourced R&D and foreign direct investment (FDI). FDI increases the number of new technology suppliers and the breadth of technologies available in the market (Luo et al., 2011; Zhang et al, 2014), which in turn gives Chinese firms access to large markets for technology.

Transaction costs. Transaction costs are important for understanding the way in which firms innovate and largely depend on asset specificity, uncertainty and the number of suppliers in a market (Williamson, 1981; Robertson & Gatignon, 1998). The availability of technology suppliers decreases the transaction costs of using the market, whereas asset specificity and uncertainty increase such costs. It is theoretically accepted that high levels of asset specificity, greater uncertainty, less transparency and greater information asymmetries in countries with weak institutions make internalizing R&D functions preferable to using the market (Xu & Meyer, 2013). However, this theoretical position may not be applicable in Chinese firms. First, although this prediction is valid in developed countries, it rests on the assumption that firms can rely on their internal R&D capabilities if and when they want to.

However, Chinese firms have insufficiently developed R&D capabilities and are therefore forced to engage in market transactions.

Second, transaction costs for Chinese firms may be less than the transaction costs for firms from developed countries operating in China. Chinese government policies are specifically designed to attract foreign high-tech firms and incentivize domestic firms to exploit the inflow of foreign technologies (Zhang et al., 2014). They also explicitly require foreign investors to transfer technology to obtain access to the market. Therefore, these policies not only increase the number of technology suppliers and the pace at which radical innovations are introduced (Zhou and Wu, 2009) but also enable Chinese firms to exploit foreign technologies by lowering the transaction costs associated with accessing external technology (and easing such access in general). Furthermore, the Chinese business system operates by means of arrangements that do not conform to the developed country model (Boisot & Child, 1996). In addition to market channels, there are significant non-market mechanisms that are driven by firm-to-firm and firm-to-government relationships. Such non-market mechanisms merit special attention because they influence the willingness and ability of Chinese firms to engage in new strategic initiatives by lowering the transaction costs faced by these firms (Wang et al., 2012).

This view is reinforced by studies that show that networking, which is strongly embedded in the operations of Chinese firms, creates quasi-market mechanisms that are further facilitated by government agencies (Boisot & Child, 1996; Wang et al., 2012). These mechanisms lead to extensive ‘boundary blurring’ in which innovation-related transactions occur within neither internal hierarchies nor market structures (White, 2000). As a result, although the transaction costs associated with open innovation are high for foreign firms, Chinese firms can use various connections to reduce these costs and compensate for their R&D weaknesses (Luo, 2003; Luo et al., 2011; Luo & Wang, 2012; Zeng & Williamson, 2007). Therefore, the transaction costs for Chinese firms to access external technology might in some cases be lower than the cost of developing internal R&D capabilities, which encourages them to actively pursue external market opportunities (Ireland et al., 2002; White & Lui, 2005).

IPR regimes. A view that is prevalent in the innovation literature is that strong IPR protection in a specific environment motivates firms to innovate (Teece, 1986; Pisano and Teece, 2007). Building on this notion, it has been suggested that the success of developed countries can be explained by the development of IP laws that offer the necessary incentives for radical innovation. However, China’s remarkable innovation output stands in direct contrast with the premise that weak IPR protection cannot facilitate radical innovation.

The Chinese institutional environment has a profound impact on the way in which firms conduct their innovation processes. As opposed to developed countries, the Chinese IPR regime still favors knowledge diffusion, offers little protection from imitators and does not apply equally to all firms (Keupp et al., 2012). IPR protection in China is flexible and can be negotiated and settled within a system of networked relationships that is controlled by government agents (Boisot & Child, 1996; Xu & Meyer, 2013). Hence, when studying innovation in emerging countries such as China, it is helpful to move away from traditional law-based definitions of IPR regimes. Although such IPR arrangements are considered to be weak under standards from developed countries, they have important implications for innovation in China because what matters in such a regime is not so much who develops and owns the intellectual property assets but who controls and regulates such assets (Boisot & Child, 1996).

Furthermore, the distinction between the legal and illegal use of external technology is not clear in China (Luo et al., 2011). Along with weak punishment for IPR infringement, this gray area has accelerated the rate of technological diffusion and enables Chinese firms that invest little (or not at all) in R&D to use the market to exploit foreign technologies and knowledge spillovers not only by using methods such as reverse engineering and hiring employees from multinational enterprises (MNEs) but also by employing networking and negotiation (Luo et al., 2011; Wang et al., 2012). Conversely, firms from developed countries that operate in China invest heavily in R&D despite the weak IPR regime because the country's market potential and low-cost talent outweigh the potential disadvantages of knowledge leakage. Chinese firms can access the knowledge pool created by foreign firms not only because of the weak IPR regime and government policies but also because multinational firms are willing to sell or licence technology (Luo et al., 2011) and because many firms gradually disclose proprietary technology when IP protection is weak to slow down competition and induce rivals to wait (Pacheco-de-Almeida and Zemsky, 2012).

An overview regarding the differences between innovation in firms from developed countries and innovation in Chinese firms is summarized below in Table 1.

Table 1 Innovation in firms from developed countries and firms from China

	Developed country firms	Chinese firms
R&D capabilities	Firms from developed countries have developed strong internal R&D capabilities over time.	Chinese firms have weak internal R&D capabilities, and time compression diseconomies do not allow them to develop such capabilities quickly.
	Because the innovation strategies of firms from developed countries rely on internal R&D capabilities, they continuously invest in R&D to sustain such capabilities.	Chinese firms' innovation strategies are designed to assimilate foreign technology, and nearly one-third of the innovative firms in China do not invest at all in R&D.
	Firms from developed countries are vertically integrated across three functional areas of innovation (R&D, manufacturing and marketing).	Chinese firms rely on organizationally disintegrated innovation systems in which functional activities are located in specialized organizations.
Transaction costs	Well-developed regulatory and socio-political institutions reduce the cost of transacting in the market.	Uncertainty and weak <i>formal</i> institutions may in theory increase transaction costs. However, <i>informal</i> institutions and non-market mechanisms decrease the difficulty of accessing external technology, change the role of contractual agreements and leading to “boundary blurring”.
	There is an implicit assumption that firms from developed countries are able to rely on their internal R&D capabilities if they want to and that transaction costs determine whether the firm uses the market or not.	Even when the transaction costs of using the market are high, Chinese firms may still not be able to rely on their internal R&D capabilities.
IPR regime	There are well-developed IPR mechanisms and regulatory institutions.	The environment favors knowledge diffusion and formal institutions offer little protection from imitators.
	IPR mechanisms, regulatory institutions and courts of law protect all firms equally well.	IPR protection is more flexible and does not apply equally to all firms. It can be negotiated and settled within networks and arrangements that are controlled by government.
	What matters is who develops and owns intellectual property.	What matters is not so much who develops and owns intellectual property, but who controls and regulates such assets, which suggests that we should move away from the traditional legally based definitions of IPR.

3. HYPOTHESES

3.1 Open innovation

Radical innovation depends on three types of knowledge; knowledge regarding each of the core technological components, knowledge regarding the way in which such components are bundled or linked together (i.e., architectural knowledge), and knowledge regarding the function and utility of technologies and how these can be used to address consumer needs (i.e., functional knowledge). Our key premise here is that open innovation is a key driver of radical innovation in Chinese firms because it enables them to shift the basis of innovation away from technology to architecture- and function-related dimensions.

From an R&D capabilities perspective, firms in developed countries introduce radical innovations by improving or redeveloping the technological components of the dominant design. By contrast, because Chinese firms can only rarely advance the technology embodied in such components, they instead focus on improving their capabilities to recombine external technologies in novel ways (Cuervo-Cazurra, 2012; Hart & Christensen, 2002). In the innovation literature, this phenomenon has been referred to as ‘architectural innovation’ (Henderson & Clark, 1990), whereby firms create radical innovations not by advancing the technological components of a product but by changing the ways in which such components are integrated into systems and by changing the links among current technologies (Christensen et al, 1998). Because the combination of external components does not require Chinese firms to understand the internal workings of such components, this innovation strategy helps them by placing a premium on understanding technical interrelationships. This enables some firms to introduce radical innovations that rely on technologies developed by their competitors, yet their competitors face substantial difficulties in matching their products in the market (Henderson & Clark, 1990).

Because Chinese firms specialize in certain functions, they also benefit from the recent fine slicing of the global value chain, the convergence of technical norms and the rise of specialized intermediaries (Luo et al., 2011). This increases the opportunities for Chinese firms to improve their combinative capabilities (Luo et al., 2011), to exploit their architectural strengths and to use open innovation to complement internal innovation. Additionally, as Chinese firms’ R&D departments are at an early stage of development, they are not committed to dominant designs and can easily abandon old architectures to create new value networks (Henderson & Clark, 1990). Chinese firms also enjoy a good functional understanding of external technologies (Wu et al, 2010) and can compete by shifting the focus away from technology to the functional characteristics of innovation (Hart & Christensen, 2002; Wu et al., 2010). In such situations, open innovation helps Chinese firms develop radical innovations that address unique functional needs and “non-consumption” in low-income markets.

Similarly, from a transaction perspective, although firms from developed countries are good at managing internal hierarchies, Chinese firms have developed capabilities for efficiently utilizing the market (Cuervo-Cazurra & Annique Un, 2010). These capabilities enable Chinese firms to better manage transaction costs by building reciprocity and trust. Transaction costs can be further lowered by government policies designed to increase the availability of technology suppliers and to encourage Chinese firms to absorb foreign knowledge (Cuervo-Cazurra, 2012; Luo et al., 2011). Lower transaction costs – together with Chinese firms’ ability to use their networks to sub-contract or outsource certain functions (Luo et al., 2011) – make using the market more beneficial. Empirical evidence

confirms this view and shows that many novel Chinese products and services have been developed by relying on accessing external complementary assets as well as external infrastructure, marketing and distribution assets (Wu et al., 2010).

Furthermore, the nature of the Chinese IPR regime means that Chinese firms can access such technologies by negotiating in a business and political system that is characterized by networked relationships and government control (Boisot & Child, 1996; Xu & Meyer, 2013). Because the IPR regime in countries such as China hinges upon the acquisition and assimilation of foreign technology (Keupp et al., 2012; Liu et al., 2011), using the market plays a salient role in helping Chinese firms overcome internal R&D weaknesses (Garriga et al., 2013). Therefore, because Chinese firms operate under a different IPR regime, this environment leads to different innovation strategies and affects the value of being more open. In summary, we expect open innovation to have a positive effect on Chinese firms' abilities to develop radical innovations.

3.2 Internal R&D

We further argue that architecture- and function-related capabilities enable Chinese firms to create radical innovations even when they conduct only limited R&D. For several reasons, Chinese firms' radical innovation strategy does not have to significantly rely on internal R&D. First, from a capabilities perspective, radical innovation involves influential ideas but does not always require developing state-of-the-art technologies. Products that undergo modest changes and straightforward modifications may nonetheless result in radical solutions with important competitive implications (Henderson & Clark, 1990). Such innovations are based on architecture- and function-related capabilities and do not require Chinese firms to be R&D intensive. Empirical research supports this view (Hart & Christensen, 2002) and suggests that Chinese firms respond to the context and constraints of emerging countries by creating efficiency-enhancing and resilient innovations that require limited R&D capabilities (Cuervo-Cazurra, 2012).

Second, most of the R&D departments of Chinese firms remain in their infancy and relying on internal R&D is therefore unlikely to be sufficient to meet their needs (Guillen & Garcia-Canal, 2009; Ramamurti, 2012). Informal institutions and non-market mechanisms can decrease innovation-related transaction costs and help Chinese firms overcome such disadvantages. For instance, the literature suggests that Chinese firms rely on government-controlled resources (Luo, 2003; White, 2000) and on political and business networks to access technology and to establish collaborative agreements. These mechanisms, along with the nature of an IPR regime that increases access to external technology, help Chinese firms develop radical innovations without requiring significant R&D investment (Cuervo-Cazurra & Annique Un, 2010; Luo et al., 2011).

Although we expect the *direct* effect of internal R&D on radical innovation in Chinese firms to be insignificant, we argue that R&D plays an important moderating role. The reasoning behind this prediction is that, first, R&D enables Chinese firms to build absorptive capacity, learn about new scientific developments, provide themselves with background knowledge and subsequently, to develop radical innovations by using the market. Because bridging external technology can be arduous (Miller et al., 2007), internal R&D helps firms to overcome barriers to adoption and to initiate knowledge flows that may lead to radical innovations (Ritala & Hurmelinna-Laukkanen, 2013). Hence, the better the firm is at identifying external knowledge, the higher the chances that it will create radical

combinations.

Second, R&D assists firms in identifying new innovation opportunities (Kafourous et al., 2012), particularly when institutions are weak and transaction costs are high. In such contexts, conducting internal R&D makes radical innovation less uncertain because the firm is familiar with some of the technologies. This further improves a firm's understanding of technical interrelationships and, as a consequence, its ability to combine external technologies in novel ways. Third, because the Chinese IPR regime facilitates the flow of foreign technology, some level of R&D activity is beneficial for building a good understanding of specific scientific fields and successfully integrating and combining external technologies (Zhou & Li, 2012; Ritala & Hurmelinna-Laukkanen, 2013). As a result, internal R&D will strengthen the role of open innovation in enhancing the EME's ability to develop radical innovations.

In summary, although open innovation is significant in enhancing Chinese firms' ability to develop radical innovations, we expect that internal R&D has, on average, a weak or insignificant *direct* effect on the development of radical innovations, acting largely as a mechanism through which Chinese firms build and accrue the absorptive capacity and combinative capabilities necessary to exploit the market. These circumstances make the innovation strategy of conducting very little (or no) internal R&D a viable option for Chinese firms. Hence:

Hypotheses: (1a) The more engaged in open innovation a Chinese firm is, the greater the development of its radical innovations will be. In contrast, (1b) a Chinese firm's internal R&D does not directly influence the development of radical innovations. However, (1c) internal R&D enhances the positive effects that open innovation has on the development of radical innovations.

3.3 Technological complexity

Whereas some radical innovations involve high levels of technological complexity, others do not. Complexity depends on the 'problem structure' (Macher & Boerner, 2012). Some radical innovations are based on a novel, yet simple, integration of a few components and on low technological interdependence (i.e., each component has little effect on other components). Nonetheless, other radical innovations involve highly interdependent architectures with a large number of components interacting in complex ways (Simon, 1962). Building on the notion that the benefits and costs of accessing the market differ for low- and high-complexity technologies (Singh, 1997), we propose that technological complexity influences how internal R&D and open innovation affects the development of radical innovations in Chinese firms. In particular, we argue that the usefulness of R&D is higher when Chinese firms develop less complex radical innovations. By contrast, the opposite occurs in the case of open innovation – in other words, its effect on radical innovation is greater when complexity is higher.

First, from an R&D capabilities perspective, our reasoning rests on the premise that complex radical innovations involve greater capability demands. They require a broad repertoire of technologies that affect and are influenced by the configuration of other technological choices (Ignatius et al., 2012). High complexity increases technological interdependencies and makes understanding such associations more difficult (Macher & Boerner, 2012; Simon, 1962). Extant research shows that a firm's own experience positively affects simpler tasks. However, when complexity increases, the positive effects of

familiarity diminish because complex problems require more critical thinking and internal teams reach their cognitive boundaries.

Such cognitive limitations (Baumann & Siggelkow, 2013) make an EME's internal R&D insufficient for complex and demanding tasks, thus decreasing its marginal effect on a firm's degree of innovativeness. By contrast, the usefulness of internal R&D increases when complexity is low because such radical innovations pose fewer challenges to the EME and rely on designs that are easier to understand. Therefore, open innovation is likely to be less beneficial for developing low-complexity innovations because Chinese firms can rely on their own R&D. In these situations, the benefits of open innovation decrease due to disruption, market exchange difficulties and costly contracting (Singh, 1997).

Similarly, transaction-cost logic, as it applies to Chinese firms, suggests that external markets are preferable to internal hierarchies when complexity is high, and vice versa. Complex radical innovations represent breaks with the past, have weak path dependence and require greater breadth and flexibility in learning (Baumann & Siggelkow, 2013; Ignatius et al., 2012). In such situations, the use of the market is likely to be more effective, enabling Chinese firms to solve complex problems, to benefit from the broad availability of foreign suppliers and to design complex configurations that might otherwise not be imagined (Almirall & Casadesus-Masanell, 2010). Although market-related costs are offset by the benefits of high-complexity technologies, low-complexity projects may not enjoy equally favorable returns (Singh, 1997). Because Chinese firms possess weak R&D capabilities, internalizing the development of complex radical innovation is difficult, costly and time consuming. By contrast, internal hierarchies are likely to yield greater gains when projects are less complex and rely on prior experience and routine-based learning. In such cases, developing low-complexity radical innovations internally is preferable because firms can avoid the cost of transacting in the market. Therefore, the marginal effects of internal R&D on the development of radical innovations are higher when complexity is low, whereas pursuing a broader search through external market opportunities is more beneficial when complexity is high (Baumann & Siggelkow, 2013).

Third, innovation outcomes depend not only on the characteristics of the problem but also on the availability of problem-solving mechanisms (Kafouros et al., 2012; Macher & Boerner, 2012; Simon, 1962), which, in turn, largely depend on the IPR regime of a given environment. Less complex radical innovations consist of "well-structured" knowledge problems, whereas highly complex radical innovations consist of "poorly structured" problems. Well-structured knowledge problems have predictable and clearly defined technological states (Macher & Boerner, 2012), which increases the likelihood that an EME can solve these problems internally. In such situations, the marginal effects of internal R&D are higher, but the usefulness of the external solutions that a weak IPR regime offers decrease.

By contrast, poorly structured problems consist of ambiguous interactions (Macher & Boerner, 2012) and therefore firms cannot create complex technologies merely by re-configuring internal components (Singh, 1997). In such situations, open innovation provides certain efficiencies in solutions' searches, which are strengthened by the weak IPR regime in China that allows Chinese firms to explore diverse solutions from foreign firms. This view is reinforced by Boisot and Child (1996), who suggest that although developed country firms adopt a "complexity reduction" strategy that entails coming to understand complexity and acting on it, the IPR regime in China encourages firms to address

complexity by means of “absorption”, which entails using the market to create risk-hedging options.

In general, open innovation is likely to be less beneficial when technological complexity is low and an EME faces fewer capability limitations (Singh, 1997). In this case, the marginal contribution of internal R&D to the development of radical innovations is likely to increase. By contrast, the effect of open innovation in driving radical innovation is greater when the underlying technologies are complex, although the effect of internal R&D is lower in such cases.

Hypotheses: (2a) The positive effects of a Chinese firm’s open innovation activities on the development of radical innovations will be stronger when technological complexity is high than when technological complexity is low. By contrast, (2b) the effects of a Chinese firm’s internal R&D on the development of radical innovations will be weaker when technological complexity is high than when technological complexity is low.

4. METHODS AND DATA

4.1 Survey data

The economic and institutional environment in China has allowed the country not only to grow rapidly but also to achieve the highest intellectual property output in the world in 2012, having overtaken the United States and Japan (WIPO, 2012). China, therefore, provides an appropriate setting for testing our hypotheses. Because the annual reports of firms do not provide information on open innovation and technological complexity, data for this analysis were drawn from an innovation survey that we initiated in Liaoning province in 2011. Liaoning is one of the fastest growing industrial regions in China and has attracted a wide range of high-tech industries.

We sent the questionnaires to a random sample of 725 firms. We targeted various industries, such as the electronics, machinery and chemical industries, that differ markedly from one another, yielding substantial variability in firm characteristics and innovation strategies. To further increase variation, we asked firms to report data for each year separately (2008/9, 2009/10, 2010/11). After removing 22 responses with missing data from the sample, a total of 234 responses remained. Of these, a number of firms reported that they did not engage in any innovative activity. These firms were thus excluded, yielding a final sample of 128 firms (N=382). Approximately one-fifth of the firms in our sample reported that they did not have a formal R&D department but used the market to innovate. Our data collection strategy allowed the firms that do not conduct formal R&D but that undertake innovative activities or engage in open innovation to be included in the sample.

The survey included questions that can be found in the widely used Eurostat Community Innovation Survey (CIS) in addition to other questions that were required to measure the key constructs in this study. These or similar questions have been used in many studies and their validity and reliability has previously been established (Laursen & Salter, 2006). Two scholars competent in both Chinese and English and with research experience in the subject area in China translated the survey questions into Chinese. To eliminate cultural bias and ensure further validity we followed a back-translation process (Zhang & Li, 2010; Zhou & Li, 2012) to identify potential misunderstandings that might arise due to translation. Items identified as problematic were either dropped or revised accordingly.

Furthermore, one of our concerns was that the manner in which Chinese firms understand innovation may differ from how firms in developed countries understand the phenomenon. To control for such potential differences, we conducted three case studies and ten face-to-face interviews with managers and employees involved in innovation prior to sending the survey. This process enabled us to appreciate what Chinese firms consider to be radical and incremental innovation and to identify problems associated with single respondent bias. It also facilitated the development of descriptive examples and definitions that were sent to those firms that were asked to complete the survey. This approach improved the quality of the data by helping us to explain the different types of innovations and collaborative activities to EME managers. Additionally, the questionnaire was designed to enable different individuals in the firm to reply to different sections, and the multiple informants approach has been shown to increase the reliability and validity of surveys in China (OECD, 2005).

5. MEASURES

5.1 Dependent variable

Because measures such as patents and sales from new products do not reflect a firm's radical innovations, our dependent variable (a firm's *degree of innovativeness*) builds on prior studies that used surveys that are specifically designed to capture a firm's innovativeness (Chang, Gong, Way, & Jia, 2013; Lee, Smith, & Grimm, 2003). Our operationalization relies on a series of survey questions that are similar to those used in the CIS (2010) and the Oslo Manual (OECD, 2005). More specifically, we asked those firms that confirmed that they developed product innovations to report what type of innovations they introduced in the three years of interest (2008, 2009, 2010). We gave firms four options that covered the spectrum ranging from minor changes to radical products: 1) minor or incremental changes to existing products, 2) products that were new to the firm, 3) products that were considered to be new to the market (China) and 4) products that were considered to be new to the world. Options 2 to 4 are consistent with the CIS (2010) and OECD (2005: 57-58), which suggest that innovations should reflect the degree of novelty. We added option 1 because we sought to measure innovativeness on a continuum ranging from minor improvements to radical changes.

To ensure that our results are not influenced by the manner in which we measure a firm's innovativeness, we used the above options to create three different measures. Our first measure uses the following weights that emphasize radical innovations: incremental=1, new to the firm=2, new to the market=3 and new to the world=4. Hence, this variable takes values from 1 to 4 with higher values indicating more radical innovations. These operationalization and weights are consistent with the conceptualization discussed in the theoretical framework and with prior studies that consider that radical innovations are those that are new to the market or new to the world (Garcia & Calantone, 2002). Nevertheless, the fact that some firms developed radical innovations does not necessarily mean that they did not introduce less radical innovations. For example, a firm can create both new-to-the-market and new-to-the-world innovations. For those firms in the sample that chose more than one option, we only considered the highest.

However, because many firms do not exclusively develop a particular type of innovation but their output is a combination of those types, one of our concerns was that our focus on the highest outcome might bias the measure. For this reason, instead of

operationalizing a firm's degree of innovativeness from 1 to 4, we considered and controlled for different combinations, which led to the creation of two alternative measures. The second measure uses the same weights (1 to 4) but takes into account all those types of innovations that firms introduced. For example, an EME that develops new-to-the-firm and new-to-the-world innovations will take the value of 6 (2+4) out of 10 (10 is the highest possible value and occurs when firms choose all the options: 1+2+3+4). The variable therefore ranges from 0 to 1. This operationalization thus assumes that a firm that develops both new-to-the-market and new-to-the-firm innovations is more innovative than a firm that creates new-to-the-market innovations only.

To construct the third measure of innovativeness, we identified and coded 15 different patterns of combinations in our data (e.g., 4; 4+3; 3; 3+2 and so on). These patterns were then sorted on a scale moving from incremental to radical innovation. This measure therefore ranges from 0 to 1 and more specifically varies from "1 out of 15" (for firms that introduce incremental innovations only) to "15 out of 15" (for firms that create new-to-the-world innovations only). The second and the third measures are similar in many ways because they explicitly consider that firms might simultaneously introduce innovations of different degrees of radicalness. However, they differ in their assumptions regarding the value of introducing less radical product innovations. The second measure assumes that firms that introduce both highly radical innovations (new to the world) and less radical innovations (new to the market) are more innovative than firms that create radical innovations only. By contrast, the third measure hinges on the assumption that the latter group of firms is more innovative than the first group. Hence, firms that focus on radical innovations only take the highest value.

5.2 Independent variables

Internal R&D: This measure refers to the degree to which an EME invests in internal R&D activities. We collected information on Chinese firms' R&D intensity by asking firms to report their internal R&D expenditures for each year separately (2008, 2009 and 2010). Following common practice, we operationalized this construct using the ratio of R&D expenditures to sales. Because one-fifth of the firms of the sample do not have a formal R&D department, the measure takes the value of zero for some firms.

Collaborative innovation: The second key explanatory variable of the study, *open innovation*, captures innovation-related collaboration between the firm and external organizations. To construct this variable, we asked firms to report whether they cooperate for innovation or have joint collaborative innovation projects with other organizations. To ensure that companies understood the different types of open innovation, we built on recent work (Dahlander & Gann, 2010) that reviewed the types of pecuniary and non-pecuniary open innovation and provided the firms with a list of different types. We were thus able to create a dummy variable with a value of 1 if the firm replied that it had conducted at least one of the following types of open innovation with external organizations: co-patenting, technology sharing, R&D, product design and development, knowledge sourcing/exchange, laboratory sharing and other forms of innovation.

Project complexity: To test the hypothesized relationships, we further needed to identify whether a firm engages in technologically complex innovation projects. To capture such variations, we asked firms about their innovation projects and the primary reasons for cooperating in R&D or innovation. Because it is difficult to identify the degree of

technological complexity (particularly for firms that engage in multiple projects), we created a dummy variable with the value of 1 for firms that reported that they become involved primarily in projects that are technologically complex.

5.3 Control variables

Collaborative innovation practices: The literature (Laursen & Foss, 2003) points to a number of firm practices that facilitate innovation by changing employee expectations regarding future rewards, that emphasize the importance of openness and that enhance employee motivation and commitment. Building on studies that reviewed such practices, we ask firms to report whether they engage in any of the following open innovation practices: 1) offering rewards and recognition to staff who integrate external technologies into existing products; 2) make their staff responsible for identifying and sourcing external technologies; 3) establish a more open and innovative culture by giving staff time to work on their own external projects and to search for solutions outside of the company's boundaries and 4) have formal plans and policies to further develop staff. We then coded the answers to each of these four questions using 1 for positive answers and calculated the total value (i.e., the variable ranges from 0 to 4). Thus, the higher the value of the variable, the greater the firm's adoption of open innovation practices.

Integration difficulty: As the theoretical framework indicates, one of the key challenges of engaging in open innovation is to integrate external technologies. To control for this effect, we asked firms to report the innovation and business problems that they face. This control relies on a dummy variable that takes the value of 1 for firms that reported that they face significant difficulties in terms of integrating external technologies into existing technologies.

Access to financial resources: Another factor that may significantly constrain a firm's innovativeness involves limitations with respect to access to finance. To control for this effect, we created a dummy variable that takes the value of 1 for the firms that reported that they experienced difficulties associated with access to financial resources.

Internal R&D department: Firms that innovate without having a dedicated R&D department may differ from those firms with an internal R&D team. To capture such variations, we created a dummy variable that takes a value of 1 for firms with an R&D department. This allowed us to include in the sample those firms that innovate without formal R&D departments and is particularly important in the context of an emerging economy.

Industry effects: As idiosyncrasies associated with various sector fixed effects can influence a firm's innovativeness, the model included a set of dummy variables to control for the different sectors in the sample. We also included dummy variables to control for lower-tech industries (e.g., resin, plastic and printing) and higher-tech industries (e.g., pharmaceutical, chemical, medical instruments and electronics).

6. RESULTS

The descriptive statistics for the model variables are provided in Table 2. As expected, the three dependent variables are highly correlated with one another. Although the correlations between the independent variables are low, we calculated the variance inflation factor (VIF) for each variable to detect potential multicollinearity. The average VIF across the models is 1.14, which is below the acceptable cut-off point of 10. Following common

practice, we mean-centered the interaction variables to alleviate potential multicollinearity problems and to increase the interpretability of the interaction terms. We further applied the residual centering procedure (Lance, 1988) to resolve multicollinearity between the interaction term and its component factors. Based on the nature of our dependent variables, we estimate the key results using ordered probit for the first measure of firm innovativeness and tobit for the other two measures.

Table 2 Descriptive statistics and correlations

	Mean	S.D.	1	2	3	4	5	6	7	8	9
1 Open Innovation	0.82	0.39									
2 Internal R&D	0.5	5.02	0.05								
3 Complexity	0.3	0.46	0.26***	0.13***							
4 Adoption of innovation practices	2.08	1.53	0.13**	0.11**	0.32***						
5 Access to finance	0.29	0.45	0.12**	-0.06	0.03	-0.11**					
6 Integration difficulty	0.05	0.21	0.10**	-0.01	0.02	0.11**	0.10**				
7 Internal R&D team	0.8	0.4	0.07	0.05	0.08	-0.05	0.07	0.11**			
8 Innovativeness measure 1	2.69	1.11	0.18***	0.03	0.21***	0.27***	0.21***	-0.04	0.32***		
9 Innovativeness measure 2	0.46	0.31	0.27***	-0.01	0.32***	0.42***	0.22***	-0.04	0.26***	0.86***	
10 Innovativeness measure 3	0.38	0.27	0.07	-0.08	0.18***	0.32***	0.11**	0	0.12	0.75***	0.79***

Notes: † p<0.10, * p<0.05; ** p<0.01; *** p<0.001. N=382.

The regression results are reported in Table 3 for the three alternative operationalizations of firm innovativeness. For the first measure of firm innovativeness, Model 1 serves as our baseline model. To test the hypotheses, we enter each two-way interaction separately in Models 2-4 and then enter all the two-way interactions in Model 5. We repeated this process for the second measure (Models 7-11) and for the third measure (Models 13-17). The results for the different operationalizations are similar and support our hypothesized effects. The only exception is Hypothesis 1a regarding the direct contribution of open innovation. This effect is statistically significant for the second measure of firm innovativeness, but not for the first and third. Hence, this hypothesis is only partly supported. By contrast, the direct effect of internal R&D on the degree of Chinese firms' innovativeness is consistently negative and highly significant across all the models and all the measures of innovativeness. This result provides support for Hypothesis 1b, suggesting that internal R&D does not directly enhance Chinese firms' ability to develop radical innovations. This finding is also consistent with our theoretical prediction that the role of internal R&D in Chinese firms differs considerably from its role in companies in developed countries.

Table 3 Regression results

	Innovativeness measure 1						Innovativeness measure 2			
	1 ordered probit	2 ordered probit	3 ordered probit	4 ordered probit	5 ordered probit	6 ordered logit	7 Tobit	8 Tobit	9 Tobit	10 Tobit
H1a: Collaborative Innovation	0.358 (1.27)	0.356 (1.29)	0.308 (1.09)	0.294 (1.01)	0.286 (1.02)	0.786 (1.52)	0.161 (3.00)**	0.16 (3.11)**	0.136 (2.48)*	0.127 (2.17)*
H1b: Internal R&D	-0.011 (-2.63)**	-0.012 (-2.77)**	-0.013 (-2.73)**	-0.011 (-2.58)**	-0.012 (-2.77)**	-0.024 (-3.00)**	-0.006 (-5.28)***	-0.007 (-5.39)***	-0.007 (-5.38)***	-0.007 (-5.38)***
H1c: Collaborative Innovation x Internal R&D		7.318 (2.44)*			8.153 (2.70)**	12.976 (2.50)*		2.067 (4.34)***		
H2a: Collaborative Innovation x Project complexity			1.254 (2.42)*		1.476 (2.83)**	2.224 (2.34)*			0.398 (3.05)**	
H2b: Internal R&D x Project complexity				-0.633 (-2.60)**	-0.699 (-2.89)**	-1.084 (-2.73)**				-0.241 (-2.58)**
Project complexity			0.167 (0.64)	0.177 (0.67)	0.154 (0.58)	0.294 (0.59)			0.089 (1.23)	0.095 (1.32)
Adoption of innovation practices	0.273 (3.94)***	0.279 (4.01)***	0.268 (3.61)***	0.264 (3.55)***	0.282 (3.78)***	0.464 (3.13)**	0.113 (6.01)***	0.114 (6.06)***	0.107 (5.42)***	0.106 (5.41)***
Access to finance	0.686 (3.36)***	0.688 (3.34)***	0.739 (3.47)***	0.715 (3.49)***	0.791 (3.70)***	1.254 (3.24)**	0.215 (3.50)***	0.214 (3.47)***	0.227 (3.64)***	0.222 (3.69)***
Integration difficulty	-1.186 (-2.24)*	-1.214 (-2.28)*	-1.193 (-2.29)*	-1.296 (-2.60)*	-1.372 (-2.73)**	-2.259 (-2.62)**	-0.33 (-2.13)*	-0.335 (-2.16)*	-0.324 (-2.15)*	-0.363 (-2.62)**
Internal R&D department	1.066 (3.63)***	1.098 (3.74)***	1.005 (3.32)***	1.045 (3.53)***	1.019 (3.35)***	1.767 (3.11)**	0.274 (3.85)***	0.281 (3.94)***	0.25 (3.41)***	0.259 (3.66)***
Industry controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cutpoint No. 1	-0.590	-0.589	-0.627	-0.609	-0.642	-1.179	NA	NA	NA	NA
Cutpoint No. 2	0.491	0.503	0.446	0.476	0.448	0.873	NA	NA	NA	NA
Cutpoint No. 3	1.245	1.264	1.201	1.238	1.216	2.221	NA	NA	NA	NA
Cutpoint No. 4	2.418	2.441	2.391	2.427	2.428	4.308	NA	NA	NA	NA
Constant	NA	NA	NA	NA	NA	NA	-0.097 (-1.02)	-0.099 (-1.06)	-0.079 (-0.84)	-0.087 (-0.91)
N	382	382	382	382	382	382	382	382	382	382
Log pseudolikelihood	-473.63	-471.306	-471.108	-469.768	-464.843	-464.158	-124.396	-121.806	-118.889	-113.983
F-statistics	NA	NA	NA	NA	NA	NA	17.81***	15.12***	39.86***	9.41***
Pseudo R ² / R ²	0.134	0.138	0.138	0.141	0.150	0.151	0.453	0.465	0.477	0.499
Mean VIF	1.12	1.12	1.16	1.16	1.16	1.16	1.12	1.12	1.16	1.16

Notes: † p<0.10, * p<0.05; ** p<0.01; *** p<0.001. The figures in parentheses are t-statistics.

Table 3 Regression results (cont.)

	Innovativeness measure 2		Innovativeness measure 3					
	11 Tobit	12 OLS	13 Tobit	14 Tobit	15 Tobit	16 Tobit	17 Tobit	18 OLS
H1a: Open Innovation	0.123 (2.40)*	0.118 (2.59)**	-0.006 (-0.08)	-0.008 (-0.12)	-0.014 (-0.18)	-0.019 (-0.25)	-0.022 (-0.31)	-0.009 (-0.14)
H1b: Internal R&D	-0.007 (-5.58)***	-0.006 (-6.31)***	-0.007 (-8.26)***	-0.007 (-8.59)***	-0.007 (-7.81)***	-0.007 (-8.21)***	-0.007 (-8.66)***	-0.007 (-8.54)***
H1c: Open Innovation x Internal R&D	2.22 (4.52)***	1.801 (4.10)***		2.442 (3.61)***			2.639 (3.78)***	2.564 (3.85)***
H2a: Open Innovation x complexity	0.46 (3.58)***	0.36 (3.58)***			0.3 (2.45)*		0.361 (2.95)**	0.338 (2.93)**
H2b: Internal R&D x complexity	-0.254 (-2.80)**	-0.19 (-4.47)***				-0.134 (-3.30)***	-0.145 (-3.84)***	-0.144 (-3.75)***
Complexity	0.087 (1.23)	0.074 (1.29)			0.021 (0.41)	0.026 (0.51)	0.017 (0.34)	0.016 (0.32)
Adoption of innovation practices	0.11 (5.61)***	0.09 (5.71)***	0.055 (3.55)***	0.057 (3.62)***	0.055 (3.43)***	0.054 (3.38)***	0.058 (3.64)***	0.058 (3.70)***
Access to finance	0.24 (3.93)***	0.195 (4.09)***	0.101 (2.05)*	0.1 (2.06)*	0.111 (2.24)*	0.107 (2.19)*	0.121 (2.49)*	0.116 (2.43)*
Integration difficulty	-0.378 (-2.75)**	-0.321 (-2.79)	-0.165 (-1.46)	-0.171 (-1.51)	-0.167 (-1.48)	-0.186 (-1.69)†	-0.2 (-1.82)†	-0.198 (-1.77)†
Internal R&D team	0.246 (3.41)***	0.21 (3.60)***	0.084 (1.45)	0.092 (1.60)	0.07 (1.14)	0.078 (1.33)	0.072 (1.19)	0.076 (1.27)
Industry controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cutpoint No. 1	NA	NA	NA	NA	NA	NA	NA	NA
Cutpoint No. 2	NA	NA	NA	NA	NA	NA	NA	NA
Cutpoint No. 3	NA	NA	NA	NA	NA	NA	NA	NA
Cutpoint No. 4	NA	NA	NA	NA	NA	NA	NA	NA
Constant	-0.077 (-0.84)	-0.023 (-0.31)	0.249 (2.19)*	0.247 (2.20)*	0.259 (2.26)*	0.251 (2.20)*	0.257 (2.30)*	0.242 (2.29)*
N	382	382	382	382	382	382	382	382
Log pseudolikelihood	-107.775	NA	-22.7663	-17.9243	-20.6061	-18.8744	-10.9168	NA
F-statistics	18.35***	97.74***	11.74***	11.77***	9.83***	29.16***	217.21***	214.98***
Pseudo R2 / R2	0.526	0.468	0.667	0.738	0.699	0.724	0.840	0.268
Mean VIF	1.16	1.16	1.12	1.12	1.16	1.16	1.16	1.16

Notes: † p<0.10, * p<0.05; ** p<0.01; *** p<0.001. The figures in parentheses are t-statistics.

To test Hypothesis 1c, a two-way interaction between open innovation and internal R&D is incorporated into Models 2, 5, 8, 11, 14 and 17. This interaction term is positive and statistically significant across the three measures of innovativeness. This result corroborates the notion that although internal R&D does not directly affect Chinese firms' ability to create radical innovations, it enables Chinese firms to benefit from open innovation. To test Hypotheses 2a and 2b, we interact open innovation and R&D with technological complexity (Models 3-5, 9-11 and 15-17). The interaction term produces a positive coefficient in all the models and thus supports the prediction that the role of open innovation in facilitating radical innovation will be stronger for firms that focus on technologically complex projects than for firms that engage in projects with lower levels of technological complexity. By contrast, the coefficient of the interaction between R&D and complexity is statistically significant but negative, which suggests that the effect of internal R&D on radical innovation is in fact adverse when technological complexity is high. The results therefore support Hypotheses 2a and 2b.

6.1 Robustness tests and additional analyses

First, we hypothesized that, on average, internal R&D helps Chinese firms build the combinative capabilities necessary to benefit from open innovation, but it does not directly affect the development of radical innovation. However, the role of internal R&D might differ across firms that engage in open innovation and those that do not engage in open innovation. For instance, it is possible that R&D is more useful for those firms that do not use the market and choose to perform all their innovation-related functions internally. To examine whether there are such patterns in the data, we re-run the model while distinguishing between firms that engage in open innovation and those firms that do not. The results of this analysis are consistent with the main results, which indicate that the effects of internal R&D are negative, on average. The results remained similar for all three measures of innovativeness and for all the estimation methods.

Second, we explored whether the role of R&D differs across firms that focus on high-versus low-complexity innovations, and the results of this sub-sample analysis were consistent with H2b. The effects of internal R&D on the development of radical innovation remained negative for firms focused on highly complex radical innovations. However, R&D positively contributed to radical innovation for those firms engaged in creating less complex technologies. This finding supports the notion that an EME's own R&D is more useful when technologies are simpler and thus within the reach of the firm's technical expertise. Once again, these results remained robust to using different innovativeness measures and estimation methods.

Third, we investigated how the effects of open innovation differ across Chinese firms. For example, its value may differ for firms that spend money on research and those that do not. When we rerun the model after splitting the sample into firms that invest in internal R&D and firms that do not, we found that the effects of open innovation on the development of radical innovations are much higher for firms that invest in internal R&D. This result provides additional support to H1c, confirming that R&D helps Chinese firms to accumulate background knowledge and develop radical innovations using the market. We also used a split sample analysis to examine how the effects of open innovation differ across Chinese firms that focus on complex innovations and those that develop less complex technologies. In line with H2a, the effects of open innovation were particularly strong and positive in the case of high complexity but either much lower or statistically insignificant for less-complex innovations (this finding was again consistent across the different measures and specifications).

Fourth, the results in Table 2 rely on an aggregate measure of open innovation that incorporates different types of external partners. To explore whether some types of open innovation are more effective than others in stimulating radical innovation, we rerun the model after breaking down open innovation into different types. Although the effects of open innovation on radical innovation were statistically insignificant for some partnerships (possibly because of the small number of observations), they were particularly positive when EME's open innovation involved foreign or domestic universities. These results are in line with the argument that whereas universities represent one of the least frequently used knowledge sources for firms in developed countries, Chinese firms compensate for internal weaknesses by relying much more on academic collaborations (OECD, 2008, 2009).

To examine whether our results regarding the role of internal R&D, open innovation and complexity change over time, we also re-estimated the models for each year separately (2008, 2009 and 2010). Once again, this alternative set of models corroborated our hypotheses. The effects of R&D, open innovation and complexity remained consistent from year to year, albeit with some variation in the level of significance due to the smaller number of observations. Finally, we examined the sensitivity of our results to changes in the estimation method. Although the Tobit estimator (Models 7-11 and 13-17) is efficient because the second and third innovativeness measures are limited dependent variables with lower and upper limits, we re-estimated the models using OLS for purposes of comparison. We also used ordered logit (instead of ordered probit) for the first measure of innovativeness. The new results reported in Models 6, 12 and 18 resemble those produced by the other estimation methods.

8. DISCUSSION AND CONCLUSION

8.1 Theoretical contributions

Our theoretical contributions lie in identifying the driving forces and innovation strategies that enable Chinese firms to develop radical innovations. This also enables us to show how these innovation strategies differ from those adopted by firms in developed countries. Our findings have several implications for innovation theory. First, we showed how the characteristics of Chinese firms and their contexts are influenced by variations in R&D capabilities, transaction costs and IPR protection and how these, in turn, affect Chinese firms' innovation strategies and the role of both internal R&D and open innovation. In contrast to conventional wisdom, we show that R&D by itself is not sufficient to enhance Chinese firms' innovativeness. Our analysis however does not necessarily imply that R&D does not matter. R&D is a mechanism through which Chinese firms build the functional and architectural capabilities necessary to develop radical innovations by exploiting the market. Thus, although research in developed countries suggests that firms that over-rely on the market may gradually lose their innovation capabilities, Chinese firms become good at combining technological components even when they might not fully understand the internal workings of these components.

Chinese firms' innovation strategies are largely facilitated by a set of policies and non-market mechanisms that affect the transaction costs of accessing external technologies and enable Chinese firms to develop radical innovations while maintaining investment in formal R&D at lower levels. In this respect, Chinese firms' innovation strategies differ considerably from strategies adopted by firms in developed countries, which are less dependent on the environment and can increase their reliance on internal R&D when the institutional regime is

weak and transaction costs are high. Therefore, although prior research suggests that MNEs in developed countries use their internal organization to compensate for ineffective host-country institutions (Zhao, 2006), it appears that Chinese firms do the opposite, i.e., they use informal institutions and exploit flexible IPR regimes to compensate for weak internal R&D capabilities. These results also support the notion that business and government networks in China lead to boundary blurring and to the creation of quasi-market mechanisms (White, 2000) that lower the cost of innovation-related transactions for Chinese firms and help firms compensate for internal R&D weaknesses by using the market.

Our study also contributes to our understanding of how institutions and country-specific idiosyncrasies influence innovation. Prior research has concentrated on firms from developed markets that internalize certain functions and that innovate in mature institutional environments that protect technological IP (Teece, 1986). Nevertheless, these practices do not explain how Chinese firms succeed in developing radical innovations. Contrary to conventional wisdom that considers weak IPR regimes to negatively affect innovation, we show that, in fact, such institutional settings can be advantageous for the innovation performance of Chinese firms, enabling firms with weak R&D capabilities to shift their innovation focus away from core technology development to functional and architectural strengths. Thus, rather than significantly investing in R&D and hoping that they will gradually catch up with developed country competitors, the innovation strategy of Chinese firms exploits inefficiencies in China's IPR environment, the increasingly fine slicing of the global supply chain (Luo et al., 2011) and the development of open markets for technology to "emulate" the innovation model and the vertically integrated organization of developed market firms.

Our second contribution to the understanding of innovation in emerging countries involves the role of technological complexity. Prior research has found that firms that develop highly complex technologies face greater competency demands and organizational costs, which subsequently increase the risk of failure (Singh, 1997). We extend this literature by demonstrating that technological complexity in Chinese firms has different effects on the benefits and disadvantages of internal R&D and open innovation and, in turn, different effects on a firm's degree of innovativeness. More specifically, we show that the role of R&D in enhancing the degree of Chinese firms' innovativeness is lower when firms focus on radical innovations that are complex. By contrast, the opposite pattern emerges when we consider the role of open innovation. The effectiveness of open innovation in increasing a firm's degree of innovativeness is lessened when radical innovations involve low complexity and well-structured knowledge problems (Macher & Boerner, 2012), but its effectiveness increases as technologies become more complex and present poorly structured problems.

This finding contradicts research focusing on firms from developed countries that suggests that a closed innovation model is more beneficial for complex projects (Almirall & Casadesus-Masanell, 2010). It seems that the dexterities required to solve poorly structured problems extend beyond Chinese firms' R&D capabilities and that therefore accessing the market proves to be advantageous. By contrast, internal R&D provides certain efficiencies in the search for solutions when radical innovations involve simpler interactions and fewer capability limitations (Singh, 1997). In such situations, its advantages for and therefore its marginal contribution to the development of radical innovations increases. Our findings also contribute to research on organizational boundaries that considers transaction costs as the main determinant of make-or-buy decisions by showing that the consequences of make-or-buy decisions are influenced by technological complexity. Although Chinese firms operate in environments

characterized by high transaction costs, we show that it nonetheless remains advantageous for Chinese firms to use the market because they can effectively combine technological components. Hence, rather than emphasizing conceptualizations that see firms as efficiency-seeking and cost-minimizing actors, our analysis suggests that Chinese firms develop radical innovations by becoming skillful combiners of components.

8.2 Managerial implications

First, prior research has suggested that firms that need to improve their technological capabilities should heavily invest in R&D and wait until they gradually become better at developing technologies. A practical implication is that Chinese firms are a special form of innovative organizations that respond to competitive disadvantages by shifting their attention away from technology development to innovations that require architecture- and function-related capabilities. This finding does not imply that managers of Chinese firms' should underestimate the importance of R&D. With respect to Chinese firms, R&D does not act in its traditional role of developing new technologies but is instead an effective tool for building the capacity to combine technological components that come from outside of the firm. In addition, instead of underestimating the innovation capabilities of Chinese firms, MNE managers from developed countries entering emerging economies should consider how they will respond to these innovation strategies, particularly when engaging in joint ventures and alliances with Chinese firms.

Second, although Chinese firms' innovation strategies may work in China, they are context specific. It is therefore unclear whether they are transferable and applicable in other countries. Similarly, given that these innovation strategies exploit certain institutional idiosyncrasies, it is less clear whether such strategies will remain effective as institutions and the IPR regime in China grow stronger. In such situations, developing innovation strategies that can be used abroad will likely become more important, which also suggests that in the future, Chinese firms might have to excel not only in function- and architecture-related innovation but also in technology-driven innovations. Managers should nonetheless recognize that these capabilities rely on different and frequently incompatible routines that may make the simultaneous pursuit of all three challenging.

Third, Chinese firms' managers should bear in mind that the relative benefits and value of internal R&D and open innovation depend on how complex the firms' radical innovations are. In addition to transaction cost considerations, managers should recognize that even when two Chinese firms possess similar capabilities, the technological complexities of their projects – and therefore the optimal make-or-buy strategy – might differ considerably. Such technological variations influence how much each firm can benefit from its own R&D and open innovation and may result in different performance outcomes. Although the effects of R&D are weak or insignificant, on average, the benefits of conducting R&D are higher when complexity is low. One interpretation of this result is that low complexity innovations pose fewer challenges and competency demands and a lower risk of failure (Singh, 1997). By contrast, when complexity is high, the value of open innovation increases, which suggests that using the market and collaborative agreements is likely to be a fruitful strategy for radical innovation.

8.3 Limitations

First, institutions, IPR regimes and transactions costs may differ in other emerging countries and such variations may, in turn, impact the manner in which Chinese firms innovate.

Examining whether our findings hold for other emerging countries might be a worthwhile avenue for future research. Second, we do not have information regarding the type of external partners that the Chinese firms studied in this research engaged with (e.g., whether they are domestic or foreign, alliances, joint ventures, licensing arrangement and co-creation partnerships). A collection of detailed data may enable future research to extend this study by examining the effects of different types of external partners on the degree of Chinese firms' innovativeness.

Due to data constraints, we were not able to observe Chinese firms' innovativeness over an extended period of time. A longitudinal analysis would enable future research to identify whether Chinese firms can develop internal R&D capabilities over time and, as a consequence, transform their innovation business models. This ability is particularly important because the increasing demand for more sophisticated products is shifting Chinese firms' strategic focus up the value chain (Luo et al., 2011). Furthermore, because emerging countries are gradually improving IPR protection, Chinese firms may be forced to change how they innovate due to changes in the rules of the game. Finally, the generalizability of our results may be limited because of firms' location in a single province in China. Examining whether our findings are generalizable to other Chinese regions and larger samples of firms would be a worthwhile goal of future research.

REFERENCES

- Almirall, E., & Casadesus-Masanell, R. 2010. Open versus closed innovation: A model of discovery and divergence. *Academy of Management Review*, 35: 27-47.
- Arora, A., Fosfuri, A., & Gambardella, A. 2001. Markets for technology and their implications for corporate strategy. *Industrial and corporate change*, 10: 419-451.
- Arora, A., Belenzon, S., & Rios, L. A. 2014. Make, buy, organize: The interplay between research, external knowledge, and firm structure. *Strategic Management Journal*, 35: 317–337.
- Awate, S., Larsen, M. M., & Mudambi, R. 2012. EMNE catch-up strategies in the wind turbine industry: Is there a trade-off between output and innovation capabilities? *Global Strategy Journal*, 2: 205-223.
- Baumann, O., & Siggelkow, N. 2013. Dealing with Complexity: Integrated vs. Chunky Search Processes. *Organization Science*, 24:116-132.
- Boisot, M., & Child, J. 1996. From fiefs to clans and network capitalism: Explaining China's emerging economic order. *Administrative Science Quarterly*, 41: 600-628.
- Chang, S., Gong, Y., Way, S.A., & Jia, L. 2013. Flexibility-Oriented HRM systems, absorptive capacity, and market responsiveness and firm innovativeness. *Journal of Management*, 39: 1924-1951.
- Chatterji, A. K., & Fabrizio, K. R. 2014. Using users: When does external knowledge enhance corporate product innovation? *Strategic Management Journal*, 35: 1427–1445. doi:10.1002/smj.2168.
- Chesbrough, H. 2003. *Open innovation: The new imperative for creating and profiting from technology*. Boston, MA.: Harvard Business School Press.
- Christensen, C. M., Suárez, F. F., & Utterback, J. M. 1998. Strategies for survival in fast-changing industries. *Management Science*, 44: S207–S220.
- Coase, R. H. 1992. The institutional structure of production. *American Economic Review*, 82: 713–719.
- Community Innovation Survey (CIS). 2010. *The Harmonized Survey Questionnaire*. Eurostat.
- Cuervo-Cazurra, A. 2012. Extending theory by analyzing developing country multinational companies: Solving the Goldilocks debate. *Global Strategy Journal*, 2: 153-167.
- Cuervo-Cazurra, A., & Annique Un, C. 2010. Why some firms never invest in formal R&D. *Strategic Management Journal*, 31: 759-779.
- Cuervo-Cazurra, A., & Genc, M. 2008. Transforming disadvantages into advantages: Developing-country MNEs in the least developed countries. *Journal of International Business Studies*, 39: 957-979.
- Dahlander, L., & Gann, D. M. 2010. How open is innovation? *Research Policy*, 39: 699–709.
- Dutt, N., Hawn, O., Vidal, E., Chatterji, A. K., McGahan, A. M., & Mitchell, W. 2015. How Open System Intermediaries Address Institutional Failures: The Case of Business Incubators in Emerging-Market Countries. *Academy of Management Journal*.
- Garcia, R., & Calantone, R. 2002. A critical look at technological innovation typology and innovativeness terminology: A literature review. *Journal of Product Innovation Management*, 19: 110-132.
- Garriga, H., von Krogh, G., & Spaeth, S. 2013. How constraints and knowledge impact open innovation. *Strategic Management Journal*, 34: 1134-1144.

- Guan, J. C., Yam, R. C. M., Tang, E. P. Y., & Lau, A. K. W. 2009. Innovation strategy and performance during economic transition: Evidences in Beijing, China. *Research Policy*, 38: 802-812.
- Guillen, M. F., & Garcia-Canal, E. 2009. The American model of the multinational firm and the “new” multinationals from emerging economies. *Academy of Management Perspectives*, 23: 23–35.
- Hart, S. L., & Christensen, C. M. 2002. The great leap: Driving innovation from the base of the pyramid. *MIT Sloan Management Review*, 44: 51-56.
- Henderson, R. M., & Clark, K. B. 1990. Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly*, 35: 9-30.
- Hermelo, F. D., & Vassolo, R. 2010. Institutional development and hypercompetition in emerging economies. *Strategic Management Journal*, 31: 1457-1473.
- Ignatius, J., Leen, J.Y.A., Ramayah, T., Hin, C.K., & Jantan, M. 2012. The impact of technological learning on NPD outcomes: The moderating effect of project complexity. *Technovation*, 32: 452-463
- Ireland, R. D., Hitt, M. A., & Vaidyanath, D. 2002. Alliance management as a source of competitive advantage. *Journal of Management*, 28: 413-446.
- Kafourous, M. I., Buckley, P. J., & Clegg, J. 2012. The effects of global knowledge reservoirs on the productivity of multinational enterprises: The role of international depth and breadth. *Research Policy*, 41: 848-861.
- Keupp, M. M., Friesike, S., & von Zedtwitz, M. 2012. How do foreign firms patent in emerging economies with weak appropriability regimes? Archetypes and motives. *Research Policy*, 41: 1422-1439.
- Lance, C. E. 1988. Residual centering, exploratory and confirmatory moderator analysis, and decomposition of effects in path models containing interactions. *Applied Psychological Measurement*, 12: 163-175.
- Laursen, K., & Foss, N. 2003. New human resource management practices, complementarities, and the impact on innovation performance. *Cambridge Journal of Economics*, 27: 243–263.
- Laursen, K., & Salter, A. 2006. Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal*, 27: 131–150.
- Lavie, D. 2006. The competitive advantage of interconnected firms: An extension of the resource-based view. *Academy of Management Review*, 31: 638–658.
- Lee, H., Smith, K. G., & Grimm, C. M. 2003. The effect of New product radicality and scope on the extent and Speed of innovation diffusion. *Journal of Management*, 29: 753-768.
- Leiponen, A., & Helfat, C.A. 2010. Innovation objectives, knowledge sources, and the benefits of breadth." *Strategic Management Journal*, 31: 224-236.
- Liu, F., Simon, D. F., Sun, Y., & Cao, C. 2011. China's innovation policies: Evolution, institutional structure, and trajectory. *Research Policy*, 40: 917-931.
- Luo, Y. 2003. Industrial dynamics and managerial networking in an emerging market: The case of China. *Strategic Management Journal*, 24: 1315-1327.
- Luo, Y., Sun, J., & Wang, S. L. 2011. Emerging economy copycats: Capability, environment, and strategy. *Academy of Management Perspectives*, 25: 37-56.

- Luo, Y., & Wang, S. L. 2012. Foreign direct investment strategies by developing country multinationals: A diagnostic model for home country effects. *Global Strategy Journal*, 2: 244-261.
- Macher, J. T., & Boerner, C. 2012. Technological development at the boundaries of the firm: A knowledge-based examination in drug development. *Strategic Management Journal*, 33: 1016-1036.
- Miller, D. J., Fern, M. J., & Cardinal, L. B. 2007. The use of knowledge for technological innovation within diversified firms. *Academy of Management Journal*, 50: 307-325.
- OECD. 2005. *Oslo Manual: Guidelines for collecting and interpreting innovation data*. Organization for Economic Cooperation and Development.
- OECD. 2008. *OECD reviews of innovation policy: China*. Organization for Economic Cooperation and Development.
- OECD. 2009. *Measuring China's innovation system National specificities and inter-national comparisons*. Organization for Economic Cooperation and Development.
- Pacheco-de-Almeida, G., & Zemsky, P. B. 2012. Some like it free: Innovators' strategic use of disclosure to slow down competition. *Strategic Management Journal*, 33: 773-793.
- Park, S. H., & Luo, Y. 2001. Guanxi and organizational dynamics: Organizational networking in Chinese firms. *Strategic Management Journal*, 22: 455-477.
- Peng, M. W. 2012. The global strategy of emerging multinationals from China. *Global Strategy Journal*, 2: 97-107.
- Pisano, G. P. and Teece, D. J. 2007. How to capture value from innovation: shaping intellectual property and industry architecture, *California Management Review*, 50 (1), 278-296.
- Ramamurti, R. 2012. What is really different about emerging market multinationals? *Global Strategy Journal*, 2: 41-47.
- Robertson, T.S. and Gatignon, H. 1998. Technology development mode: a transaction cost conceptualization. *Strategic Management Journal*, 19, 515-531.
- Ritala, P., & Hurmelinna-Laukkanen, P. 2013. Incremental and radical innovation in coopetition—the role of absorptive capacity and appropriability. *Journal of Product Innovation Management*, 30: 154-169.
- Simon, H. A. 1962. The architecture of complexity. *Proceedings of the American Philosophical Society*, 106: 467-482.
- Singh, K. 1997. The impact of technological complexity and interfirm cooperation on business survival. *Academy of Management Journal*, 40: 339-367.
- Teece, D. J. 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy*, 15: 285-305.
- Wang, C., Hong, J., Kafourous, M., & Wright, M. 2012. Exploring the role of government involvement in outward FDI from emerging economies. *Journal of International Business Studies*, 43: 655-676.
- White, S. 2000. Competition, capabilities and the make, buy or ally decisions of Chinese state-owned firms. *Academy of Management Journal*, 43: 324-341.
- White, S., & Lui, S.-Y. 2005. Distinguishing costs of cooperation and control in alliances. *Strategic Management Journal*, 26: 913-932.
- Williamson, O. E. 1981. The economics of organization: The transaction cost approach. *American Journal of Sociology*, 87: 548-577.

- World Intellectual Property Organization (WIPO). 2012. World intellectual property indicators. http://www.wipo.int/export/sites/www/freepublications/en/intproperty/941/wipo_pub_941_2012.pdf. Accessed 4 February 2013.
- Wu, X., Ma, R., & Shi, Y. 2010. How do latecomer firms capture value from disruptive technologies? A secondary business-model innovation perspective. *IEEE Transactions on Engineering Management*, 57: 51-62.
- Xu, D., & Meyer, K.E. 2013. Linking theory and context: 'Strategy research in Emerging Economies' after Wright et al. (2005). *Journal of Management Studies*, 50: 1322-1346.
- Zeng, M., & Williamson, P. 2007. *Dragons at your door: How Chinese cost innovation is disrupting global competition*. Boston, MA.: Harvard Business School Press.
- Zhang, Y., & Li, H. 2010. Innovation search of new ventures in a technology cluster: The role of ties with service intermediaries. *Strategic Management Journal*, 31: 88-109.
- Zhang, Y. A., Li, Y., & Li, H. 2014. FDI spillovers over time in an emerging market: The roles of entry tenure and barriers to imitation. *Academy of Management Journal*, 57: 698-722.
- Zhao, M. 2006. Conducting R&D in countries with weak intellectual property rights protection. *Management Science*, 52: 1185-1199.
- Zhou, K. Z., & Li, C. B. 2012. How knowledge affects radical innovation: Knowledge Base, market knowledge acquisition, and internal knowledge sharing. *Strategic Management Journal*, 33: 1090-1102.
- Zhou, K. Z., & Wu, F. 2009. Technological capability, strategic flexibility, and product innovation. *Strategic Management Journal*, 31: 547-561.

