Foreign competition, domestic knowledge base and innovation activities: evidence from Chinese high-tech industries

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Abstract

Using panel data analysis for a sample of Chinese high-technology industries from 1998 to 2008, this study examines how industry characteristics affect industry innovation activities. Differing from existing studies, our research considers the impact of foreign competition on innovation activities at industry level in a large emerging economy. The results indicate that the intensity of competition from foreign invested enterprises (FIEs) and domestic skill intensity affect industry buy and make activities. Foreign competition is positively associated with the intensity of buy activity, but negatively affects the intensity of make activity. Further, the findings show that domestic skill intensity weakens the impact of foreign competitive pressure on innovation activities. Our empirical evidence has important policy implications.

Keywords: Buy and make innovation activities; foreign competition; domestic skill intensity; Chinese high-technology industries

1. Introduction

Academics and managers have become increasingly aware of the importance of innovation. Significant progress has been made in understanding performance implications or outcomes of innovation activities (Bogliacino and Pianta, 2013; Carpenter and Nakamoto, 1989; Cassiman and Veugelers, 2006; Guan and Chen, 2013; Li and Wu, 2010; Prajogo and Ahmed, 2006; Roberts and Amit, 2003). There are different types of innovation activities, such as make and buy. The former involve developing new products and technology internally, whereas the latter acquire new technology through outsourcing externally (Guo, 2008). Different innovation activities may have profound implications for building industry technological capability. Despite the importance of innovation activities, most existing studies tend to take buy and make innovation activities as given without investigating why such activities occur in the first place; not until recently has what lies behind and promotes make and buy activities been investigated (Cacciatori and Jacobides, 2005).

Increasing research interest has been devoted to the relationship between sector-level dynamics, industry architectures and innovation activities (Castellacci, 2008; Breschi et al., 2000; Jacobides and Winter, 2005, 2012; Jacobies et al., 2006; Malerba, 2002, 2005). A number of studies have highlighted that knowledge regimes, market structure, and the degree of embodied technological change of sectors affect innovation (Malerba, 2002, 2005; Jung and Lee, 2010; Jacobides and Winter, 2012). However, few studies examine how foreign competition affects make and buy innovation activities, with little attention given to the high-tech sectors of emerging economies. Therefore, the relationship between foreign competition and industry innovation activities is still not well understood in the context of emerging economies.

Building on the industry-based view and knowledge-based theory (KBT), we examine whether foreign competition and industry knowledge base influence the intensity of make and buy activities in high-tech industries, and emphasise that the intensity of make and buy activities is industry contextual dependent. Confronted with increasing foreign competition in emerging economies, domestic industries might respond to such competition differently when conducting innovation activities. Hence, we examine a fundamental question of what drives the intensity of buy and make activities in the face of intensified foreign competition in emerging economies. Combining insights from the industry-based view and the KBT enables us to shed new light on the determinants of industry innovation activities and in so doing address an important research gap presented in existing studies, where the impact of foreign competition on innovation activities, and its inter-relationship with industry knowledge base, has been understudied.

Chinese high-tech industries represent an exciting laboratory for examining the relationship between the context of high-tech industries and innovation activities. Such industries have been successful in driving the country's economic growth and have undergone substantial dynamic changes due to economic transition from a centrally planned economy to a market economy (Li and Wu, 2010; Liu and Buck, 2007). Supporting innovation is the priority of governmental industry policy. Our research setting also enables us to extend existing studies by analysing how competition from foreign invested-enterprises (FIEs) affects the intensity of make and buy activities in China, a country which is the largest recipient of foreign direct investment (FDI) in the developing world and has maintained this position for nearly 20 consecutive years (MOFECM, 2010). The increasing presence of FIEs may affect the domestic market structure and intensify industry competition, thus affecting industry innovation activities.

Our study makes a number of contributions to extant literature. First, in contrast to most existing studies that mainly focus on the relationship between innovation activities and performance; we examine in detail how the intensity of innovation activities is affected by foreign competition and industry knowledge base in Chinese high-tech industries. It is important to examine the innovative activities of these high-tech sectors in the context of foreign competition, as these sectors in emerging economies are the most dynamic, technological leaders (Liu and Buck, 2007). Hence, the findings from our research help to provide new insights into domestic innovation activities and enhance our understanding of how innovation activities are contingent on industry contextual factors. In particular, we explicitly examine how the intensity of foreign competition affects innovation activities. This helps to shed new light on the impact of FIEs in an emerging economy.

Second, we move beyond examining the individual impact of industry characteristics and consider the interaction effect between foreign competition and skill intensity across industries. Informed by the KBT, we investigate how the industry knowledge base which was measured by industry skill intensity affects the intensity of buy and make activities both directly and indirectly through interaction with foreign competition. The findings from our study help to enhance our understanding of how the interrelationship between domestic skill intensity and foreign competition shapes make and buy activities at the industry level.

Third, adopting industry level analysis enables us to draw some unique insights into the determinants of industry innovation activities. It is difficult to generalise the results based on individual firms to the whole economy or industries. In contrast, industry-level studies are able to detect the pattern or tendency of innovation activities in a given section or capture the impact of changes in industry structures. Firms operating in the same industry are likely to share the same technological opportunities, knowledge base and market structure (Pavitt, 1984; Breschi et al., 2000; Dosi et al., 2006; Guo, 2008; Guan and Chen, 2009; Li, 2011; Malerba, 2005). The strength of industry-level analysis enables us to account for the technological heterogeneity across industries in an effective way, whereas such heterogeneity is generally captured in a limited way using industry dummy variables in firm-level studies.

Such crude industry proxies are insufficient to capture the trend of industry development and competitive pressure precisely. In this regard, our industry level analysis complements findings based on individual firms.

Finally, conducting panel data analysis, we treat innovation activities as a dynamic process. Such an empirical setting, thus, differentiates our research from those based on a cross-sectional research design. In addition, a panel data analysis at firm level excludes crucial information on new entry and exit in an industry. This omission may produce biased results, whereas this problem does not appear in industry analysis (Bogliacino and Pianta, 2013). Thus, the evidence based on industry analysis enhances our understanding of how industry contextual factors influence make and buy activities and has important policy implications for both China and other emerging economies.

The remainder of the paper is structured as follows. The next section discusses the theoretical framework for this empirical study and presents the research hypotheses. Section 3 specifies the empirical model and introduces our data. The estimation and results are presented in Section 4. These are discussed in Section 5, which concludes with policy implications.

2. Theory and hypotheses

Previous research on the sectoral systems of innovation has proposed the relationship between the characteristics of the innovative process and patterns of innovation in different historical periods and industrial settings (Dosi, 1988; Freeman et al., 1982; Nelson and Winter, 1977; Pavitt, 1984). Technological paradigms are regarded as a “pattern” of solution to selected technological problems, the distinct trajectories followed by industrial sectors and the related web of vertical linkages between sector-specific technological regimes and trajectories (Archibugi, 2001; Castellacci, 2008; Marsili and Verspagen, 2002; Malerba, 2002; Nelson and Winter, 1982; Pavitt, 1984). Specifically, technological regimes can be characterised by four main aspects, namely technological opportunities, properties of the knowledge base, appropriability, and cumulativeness conditions. Some researchers have provided empirical evidence for the relationship between the patterns of innovation activities and the technological regime in a sector (Castellacci, 2008; Breschi et al., 2000; Malerba, 2002). In the context of catch-up by latecomers, several studies have adopted the perspective of technological regimes to examine technological catch-up by Korean and Taiwanese industries (Lee and Lim, 2001; Lee et al., 2005; Park and Lee, 2006). More recently, Jung and Lee (2010) have suggested that the patterns of sectoral technological catch-up in Korean industries are related to the extent of the explicit nature of knowledge, the level of concentrated markets and the exposure to the world market as well as technological cycle.

Existing studies have enhanced our understanding of the sectoral patterns of innovation activities. However, these studies have typically focused on developed countries. Few studies have extended this line of research to the context of emerging economies that have attracted a large amount of FDI and increasing foreign competition. This competition has had a profound impact on local innovation activities. We know relatively little about how foreign competition affects the intensity of make and buy activities in the context of emerging economies. Moreover, existing studies have not investigated how domestic skill intensity interacts with foreign competition and jointly affects the extent of buy and make activities. To remedy this omission, we adopt the industry-based view and the KBT to examine the role of foreign competition and domestic skill intensity in make and buy activities in the context of an emerging economy.

Industry competition plays a critical role in determining strategic activities within an industry (Porter, 1990). Adopting the industry-based view enables us to take foreign competition into account when examining the intensity of buy and make activities across high-tech industries. More specifically, there is much yet to be learned about the structures through which innovation is likely to occur in a given industry (Brunnermeier and Cohen, 2003; Bogliacino and Pianta, 2013; Chang, and Shih, 2005). An investigation of industry competition that may affect the intensity of buy and make activities represents a temporal development in the literature, from an emphasis on the firm to the identification of the impact of industry forces on innovation activities more broadly (Ahuja et al., 2008; Jacobides and Winter, 2005, 2012). Based on this rationale, competitive intensity is considered the most fundamental force affecting buy and make activities (Ahuja et al., 2008; Li, 2011). Further, the consideration of competitive intensity may lead to a more "nuanced understanding" of the relationship between innovation activities and industry structure (Ahuja et al., 2008). Industry contextual factors ultimately determine the number and types of innovative actors across sectors. Hence, the intensity of buy and make innovation activities differs systematically across sectors (Malerba and Orsenigo, 1997). In confirming the salience of industry structure in technical change, prior research suggests that to understand where innovations come from, it is important to move beyond the study of individual firms to specify conditions in the industry context (Afuah and Utterback, 1997; Edquist, 2005; Klevorick et al., 1995).

More importantly, the influence of foreign competition cannot be examined in isolation since the domestic knowledge base may affect local response to foreign competition, thus influencing industry innovation activities. The KBT highlights effective creation, acquisition and utilisation of knowledge as crucial to innovation activities (Filatotchev et al., 2011). Hence, adopting the KBT at the industry level helps to explain why different innovation activities are pursued in different industries and under what conditions industry knowledge base influences innovative dynamics (Guo, 2008; Hu, 2001; Nelson and Winter, 1982). Informed by the KBT, we argue that industry skill intensity constitutes an important industry contextual factor affecting the intensity of make and buy activities

(Mudambi, 2008). Industries with different levels of skill intensity may respond to foreign competition accordingly when conducting innovation activities as buy and make activities are constrained by the industry reservoir of knowledge sets and quality of skilled labour (Furman, Porter, and Stern, 2002). Hence, the KBT helps to underpin the role of industry skill intensity in innovation activities.

In summary, the industry-based view helps to explain how foreign competition may affect the intensity of industry buy and make activities, while the KBT underpins how industry skill intensity influences industry innovation activities directly and indirectly through interaction with foreign competition. Our research moves beyond the direct impact of foreign competition by considering conditions under which foreign competition has a great impact on the intensity of make and buy activities. This integrated framework helps to capture the pattern of innovation activities within an industry and builds on the premise that innovation activities are shaped or bounded by industrial context (Jacobides and Winter, 2005, 2012; Nelson and Winter, 1982). We derive a number of testable hypotheses based on our framework.

2.1 Foreign competition and industry buy and make activities

The relationship between competition and innovation should be approached by specifying the competition context and the type of innovation activities in order to be judged relative and meaningful (Tang, 2006). We focus on the relationship between foreign competition and buy and make activities on the basis that the extent of competition from FIEs in an industry is likely to affect innovation activities. Typically, where make and buy activities are considered, existing studies focus on firm-level factors such as internal resources and capabilities (e.g. Parmigiani, 2007; Veugelers and Cassiman, 1999). But industry-level factors should not be ignored, given that context shapes innovation activities and may therefore affect the intensity of make and buy activities in an industry. Specifically, competitive pressures in the industry may shape the form of innovation activities (Veugelers, 1997; Veugelers and Cassiman, 1999; Sakakibara and Porter, 2001). We account for the influence of foreign competition in the intensity of make and buy activities based on previous studies that have sought to consider the role of foreign competition in productivity (Castellacci, 2007), pioneering innovation (Li and Vanhaverbeke, 2009), and environmental innovation (Brunnermeier and Cohen, 2003).

Addressing the role of foreign competition in the intensity of buy and make activities, we highlight a contextual factor that cannot be understood by looking at the level of individual firms. FIEs possess both country and firm specific capabilities that differ substantially from those originating in domestic industries (Kogut, 1985; Wiersema and Bowen, 2008). Therefore, FIEs that compete for both the local market and international markets may exert a significant impact on the industry structure in the host country (Colantone and Sleuwaegen, 2010). In altering the domestic industry structure, competition intensity from FIEs may be an important element in shaping the nature of innovation activities since industry structure shapes, in part, the nature of activities pursued (Jacobides and Winter, 2012). Domestic innovation activities, then, may be inhibited by the intensity of foreign competition.

If competitors within an industry are an important source of information for innovation, sourcing knowledge externally (or buy activities) will become a dominant mode of innovation, and domestic industries will typically rely more on buy activities to catch up (Li and Wu, 2010). Buy activity stresses the advantage of utilising external knowledge, which leads to time gains relative to a make activity (Veugelers and Cassiman, 1999). In addition, the life cycle of high-tech industries is short lived and constantly needs to conduct innovation activities in response to changes in the market environment. Such an industry context may induce buy activities (Guo, 2008). When foreign competitors rapidly move into local markets, speed becomes an important attribute for local firms. Buy activities represent an effective way of building competitive advantage in a timely fashion. Unlike make activities which are subject to path dependency (Nelson and Winter, 1982) and time compression diseconomies (Dierickx and Cool, 1989), buy activities may therefore be more prominent in industries where speed is important.

On the other hand, when the level of competition from FIEs is modest, make activities may become a dominant mode of innovation in the industry, subsequently focusing on in-house innovation in order to establish technological capabilities and gain technology dominance (Brunnermeier and Cohen, 2003; Li, 2011; Li et al., 2001). For example, Castellacci (2007) suggests that new technological opportunities are more effectively exploited domestically when the sector is not exposed to foreign competition on the basis that the local industry has the time to adopt, implement, and commercialise the new technologies in the home market first, before competing in the international arena. Therefore, the pattern of industry innovation is contingent on the balance of risk and speed associated with buy and make activities in the presence of intensified foreign competition. We propose the relationship between the intensity of innovation activities and the level of competition from FIEs as follows:

H1a. The intensity of foreign competition in an industry is positively associated with the extent of buy activities in that industry.

H1b. The intensity of foreign competition in an industry is negatively associated with the extent of make activities in that industry.

2.2 Knowledge base of skill intensity and industry buy and make activities

The KBT emphasises the characteristics of employee skills and their relative contribution to value creation (Lepak and Snell, 2002). Extending the KBT to the industry knowledge context, variations in the industry knowledge base may provide incentives or impose constraints on buy and make activities (Marsili and Verspagen, 2002), therefore shaping innovation activities (Cacciatori and Jacobides, 2005). The domestic skill intensity is regarded as one of the principal characteristics of knowledge capital and constitutes a key component of the industry knowledge base (Carr et al., 2001). Innovation activities are largely conditioned on the availability of innovation-related personnel of an industry (Borensztein et al., 1998; Durham, 2004; Glass and Saggi, 2002; Marvel and Lumpkin, 2007; Reagans and Zuckerman, 2001). An increase in industry skill intensity will then positively affect innovation activities through its effect on knowledge capital (Marin and Bell, 2006; Lepak and Snell, 2002). Thus, domestic skill intensity in an industry is associated with value creation through innovation activities and is crucial for both in-house innovation and outsourcing-based innovation activities (Marin and Bell, 2006). There are two main reasons.

First, the industry skill intensity represents a necessary condition for innovation, which is consistent with industry-level literature, highlighting the importance of industrial R&D in technological innovation (Bogliacino and Pianta, 2013; Malerba, 2005; Malerba and Orsenigo, 1996). Skilled personnel are fundamental to the industry knowledge base and create a stock of distinct knowledge that leads to new technology development and more innovations (Cacciatori and Jacobides, 2005). Skill intensity is necessary for the complex new knowledge to be interpreted and utilised for purposes of innovation. Hence, new technologies and skill intensity are complementary (Goldin and Katz, 1998). Specifically, a larger number of scientists and engineers raise the industrial incentives to invest in new technology (Kiley, 1999), whereas a lack of skilled personnel is an identified obstacle to industry innovation (Mohnen and Röller, 2005). When an industry has established a strong knowledge base, make activities can continuously accumulate technological knowledge and construct innovative advantages (Malerba and Orsenigo, 1997).

Second, both make and buy activities depend on the pool of skilled personnel (Lepak and Snell, 1999). For make activities, a sufficient level of skill intensity helps to draw on the accumulated stock of industry knowledge for internal innovative activities (Breschi et al., 2000). In the context of a buy activity, skill intensity allows for the modification and improvement of external knowledge to fit specific applications, processes and routines (Veugelers and Cassiman, 1999), thus enhancing the effectiveness of buy activities (Head and Ries, 2002). In this sense, developing innovation either internally or externally rests on the ability of skilled personnel in an industry.

Prior research has highlighted the importance of knowledge environments which underpin innovation activities in an industry (Malerba, 2005); as well as knowledge resources which devoted to innovation have a profound impact on innovation performance in an industry (Liu and Back, 2007; Marsili and Verspagen, 2002). Extending this line of research, we argue that domestic skill intensity is essential to process new knowledge for innovation, whether derived from the accumulated industry knowledge base through make activities or acquired externally through buy activities. Our discussion leads to the following hypothesis.

H2. The domestic skill intensity in an industry is positively associated with the extent of both buy and make activities in that industry.

2.3 Interactions between foreign competition and industry knowledge base

We have hypothesised the individual effect of foreign competition and domestic skill intensity on the pattern of innovation activities. However, these industry characteristics may be interdependent and have a joint impact on the intensity of both buy and make activities.

Thus, we further assess whether these factors interact with each other in shaping the intensity of industry innovation activities.

As discussed above, skill intensity is important for both buy and make activities and affects the pattern of innovation directly (Blonigen and Taylor, 2000; Furman et al., 2002; Marin and Bell, 2006). Apart from its direct effect, skill intensity may also moderate the impact of foreign competition on industry innovation activities through interaction effect. In an industry with a high level of skill intensity, make activities can tap into the existing knowledge base even when the level of competition from FIEs is high. The impact of competition from FIEs on innovation activities is likely to be weakened when the industry is well-endowed with highly skilled personnel (Breschi et al., 2000; Malerba and Orsenigo, 1997). In other words, a high level of skill intensity may encourage make activities in the face of foreign competition since such an industry is likely to enjoy superior access to technological capabilities and a large pool of scientists and engineers (Brunnermeier and Cohen, 2003; Veugelers and Cassiman, 1999). In this regard, the high level of skill intensity helps to alleviate the impact of competitive pressure from FIEs on make activities (Filatotchev et al., 2011; Guo, 2008; Li, 2011).

On the other hand, make activities may be less prominent if foreign competition is intensified and skill intensity is relatively low, given that the level of skill intensity represents the foundation of innovation in an industry (Kogut and Chang 1991; Li and Wu, 2010). As we discussed above, in the face of strong foreign competition, buy activities become more important because of the speed needed to respond to such competitive pressure. Buy activities allow domestic industries to access new technology developed externally. Such access to new knowledge is vital to domestic industry infrastructure characterised by dynamic and complex technological environments (Guo et al., 2013). Moreover, domestic industries with the low level of skill intensity may find it difficult to compete against foreign competition and may rely on buy activities to upgrade their technological knowledge base. Some studies have found that a sufficient number of R&D-related personnel have a positive association with in-house innovation (Marvel and Lumpkin, 2007; Reagans and Zuckerman, 2001). This implies that buy activities are more likely to be observed in an industry with a low level of skill intensity and high level of foreign competition (Blonigen and Taylor, 2000). Building on this line of research, we argue that domestic skill intensity may weaken the effect of competitive intensity from FIEs on the pattern of innovation activities. This implies that a higher level of domestic skill intensity is able to offset the negative impact of foreign competition on make activities and weakens the positive impact of foreign competition on buy activities. Taken together, the effect of foreign competitive pressure on the intensity of buy and make activities is contingent primarily on the level of skill intensity. In other words, the domestic skill intensity plays a conditioning role in the foreign competition-make and buy relationship: an industry with a high level of skill intensity encourages make activities and reduces buy activities in the presence of foreign competitive pressure. Hence, we propose:

H3a. Domestic skill intensity weakens the negative relationship between foreign competition intensity and the extent of make activities in an industry.

H3b. Domestic skill intensity weakens the positive relationship between foreign competition intensity and the extent of buy activities in an industry.

3. Data and Methodology

3.1 Data

Our panel data from 1998 to 2008 were drawn from the *China Statistics Yearbook on High Technology Industry* in various years (2003, 2005 and 2009) which were collected by the China National Bureau of Statistics (NBS). Chinese high-tech industries are divided into 17 sub-sectors according to the NBS industrial classification system. The dataset includes Medical and Pharmaceutical Products (with 3 sub-sectors), Aircraft and Spacecraft (with 2 sub-sectors), Electronic and Telecommunications Equipment (7 sub-sectors), Computer and Office Equipment (3 sub-sectors) and Medical Equipment and Meters (2 sub-sectors). A list of sub-sectors of Chinese high-tech industries has been included in the Appendix. Only firms with a sales value of over 5 million RMB were included in the yearbook. The dataset has been used in several previous studies (e.g. Liu and Buck, 2007; Li and Wu, 2010). The unit of analysis in this study is sub-sectors within high-tech industries and the total observations are 170, given that we use the first difference of the variables in the system equation as instrumental variables. The variables used in the estimation are measured as follows[2]

3.2 Variables

Dependent variables

Make activities: the ratio of expenditure on new product and technology development to the total number of domestic firms in a sub-sector (Liu and Buck, 2007; Li and Wu, 2010).

Buy activities: the ratio of expenditure on importing technology abroad and purchasing technology locally to the total number of domestic firms in a sub-sector. The expenditure on technology outsourcing includes the purchase of design knowledge, formulae, drawings, patents, know-how and key equipment closely related to new product development (Li, 2011; Liu and White, 1997).

[2] These variables are deflated using the appropriate price indices, i.e. the general price index and the fixed asset price index for the book value of fixed capital.

Explanatory variables

The intensity of competition from FIEs: the share of output of FIEs in the total output of an industry. A high share of output produced by FIEs represents a high level of the competitive intensity of FIEs in a subsector (Palmer and Wiseman, 1999).

Domestic skill intensity: the ratio of local scientists and engineers to the total number of local employees in a sub-sector (Schilling and Steensma, 2001).

Control variables

Industry concentration: the ratio of total output value to the total number of firms in a sub-sector. The higher the ratio, the higher the level of concentration a sub-sector has (Lederman, 2010; Rothaermel, 2001).

Capital intensity: the share of the book value of fixed assets in the total output value of a sub-sector.

Export intensity: the ratio of export sales to total output value of a sub-sector which is used to measure the intensity of exposure to international markets.

We used the subsector of Electronic and Telecommunications Equipment as a baseline industry and created industry dummy variables accordingly and included year dummies.

3.3 Estimation Technique

Following Section 2, buy and make activities are considered a function of industry foreign competition and industry knowledge base which together form the estimating equations below:

$$Buy_{it} = \alpha_0 + \beta Industry_{it} + \chi Year_t + \delta_i IC_{it} + \Pi_i Control_{it} + \varepsilon_{it}, \qquad (1a)$$

$$Make_{it} = c_0 + \phi Industry_{it} + \varphi Year_t + \gamma_i IC_{it} + \Gamma_i Control_{it} + \omega_{it}, \qquad (1b)$$

In Equations (1a) and (1b) the dependent variables, Buy and Make, denote innovation activities. A make activity is referred to as in-house innovation, whereas outsourcing new technology externally is regarded as a buy activity. IC represents foreign competition and skill intensity which are the main determinants of innovation activities in an industry. Control variables include industry concentration, capital intensity and export intensity. Industry and year are sets of industry and time dummies that are used to control for the fixed effects of industry variations within high-tech industries and time variations in the estimation.

Buy and make activities may be chosen simultaneously. Therefore, we need to estimate panel system equations by considering the simultaneity of buy and make activities. A system is a group of equations containing unknown parameters. Systems are estimated by taking into account the interdependences among the equations in the system (Wooldridge, 2002). In our case, Eqs (1a) and (1b) in the system are estimated simultaneously using the generalized method of moments (GMM). This simultaneous approach takes account of correlations in the residuals across equations and allows us to consider the interdependence of make and buy innovation activities. Such an empirical approach enables us to treat buy and make as interdependent, and these two types of activities are not mutually exclusive.

4. Empirical results

Table 1 reports the descriptive statistics and the matrix of correlation coefficients of the variables used in the analysis. On average, firms in Chinese high-tech industries spend 3.1 million RMB on new product and technology development (the make activities) and half million RMB on purchasing new technology externally. It is shown that there are substantial sub-sectoral variations in innovation activities. The range of spending on new product and technology development is between 27.5 million and 0.02 million. While firms on average in the subsector of manufacturing and repairing aircraft spend 3.3 million RMB on outsourcing technology externally, those in the office equipment subsector only spend 0.04 million. On average, skill intensity accounts for 5.7% of total local employees in Chinese high-tech industries.

The results from estimating panel system equations are summarised in Table 2. Model 1 was estimated by including all the explanatory variables, whereas Model 2 includes the interaction terms between foreign competition and industry skill intensity. The results from Model 1 indicate that the variable for the intensity of competition from FIEs has a positive impact on the intensity of buy activities, but a negative effect on the intensity of make activities, as proposed in Hypotheses 1a and 1b, which state that the competitive intensity from FIEs is positively associated with the extent of buy activities, but negatively affects the intensity of make activities in a sub-sector. These results suggest that FIEs influence industry innovation activities significantly in Chinese high-tech industries. The variable of skill intensity is positively significant in Model 1 in both buy and make equations, but insignificant in Model 2 where the interaction term between foreign competition and domestic skill intensity was included. Thus, Hypothesis 2 received partial support.

Insert Tables 1and 2, near here

In Model 2, we added the interaction terms between foreign competition and domestic skill intensity. The results show that the interaction terms between foreign competition and domestic skill intensity are significant in the make equation and the buy equation. The results show that domestic skill intensity reduces or mitigates the negative impact of foreign competition on the intensity of make activities, implying that make activities still take place even though the level of foreign competition is high. In other words, foreign competition has a smaller negative impact on make activities in the presence of a higher level of domestic skill intensity. On the other hand, domestic skill intensity weakens the positive impact of foreign competition on the intensity of buy activities. This suggests that foreign competition has a smaller positive impact on the intensity of buy activities when the level of domestic skill intensity is high. There is an inter-relationship between foreign competition and domestic skill intensity in both make and buy equations. Hence, Hypotheses 3a and 3b are supported.

In terms of control variables, the variable of industry concentration is significant in the make equation, indicating that industry concentration has a positive impact on the intensity of make activities, but is partially significant in the buy equation. Export intensity is insignificant in the make equation, but significant in Model 2 in the buy equation. The variable of capital intensity is significant in the buy equation. It positively influences the intensity of buy activities. This implies that high capital intensity is associated with buy activities.

5. Discussion and conclusion

Using panel data for Chinese high-tech industries, we examine the impact of industry characteristics on industry innovation activities (i.e. make and buy activities). As the level of foreign competition and domestic skill intensity differ from sector to sector, any efforts to understand the pattern of innovation activities need to consider sectoral differences and the interrelationship between industry competition and industry skill intensity (Breschi et al., 2000; Dosi et al., 2006; Malerba, 2004; Pavitt, 1996). Thus, it is important to understand how foreign competition and domestic skill intensity affect innovation activities in an emerging economy where a great effort and considerable resources are devoted to catching up with technological leaders in developed countries. In particular, buy and make innovation activities are vital to emerging economies that aim to climb technology ladders and break out of technological dependency (Hua and Mathews, 2008; Li and Wu, 2010).

We have found that foreign competition is the most influential factor affecting the intensity of both buy and make activities in Chinese high-tech industries. It is positively associated with the degree of buy activities. The findings indicate that intensive foreign competition in the domestic market drives buy activities. In contrast, foreign competition is negatively associated with make activities. The results suggest that buy activities become a quick means to upgrade technology in the face of foreign competition, whereas make activities may be too slow to pre-empt competitive threats in this scenario. Hence, make activities are feasible when industries face less foreign competition. There is a positive association between domestic skill intensity and innovation activities in high-tech industries. These findings show that domestic skill intensity is crucial to industry innovation activities. While our findings are consistent with previous research which found that FIEs play an important role in the technological upgrading of Chinese industries (Guo, 2008; Liu and Buck, 2007), we have moved a step further to delineating the differential impact of foreign competition on make and buy innovation activities in Chinese high-tech industries.

We have further considered the interaction effects between foreign competition and industry skill intensity. Our analysis reveals that industry skill intensity does not only have a direct impact on industry innovation activities, such as make and buy activities, but also affects the strength of foreign competition on such innovation activities. Specifically, the level of skill intensity mitigates the negative impact of foreign competition on make activities. In other words, the industry with a high level of skill intensity will be able to offset the impact of foreign competition on make activities. Consistently, we have found that industry skill intensity also reduces the positive impact of foreign competition on the intensity of buy activities. Buy activities are less likely to be a dominant mode of innovation activities in an industry with abundant skilled labour even when the competition from FIEs is high.

Taken together, our results indicate that competition from FIEs appears to drive both make and buy activities, whereas industry skill intensity is a crucial condition under which make and buy innovation activities occur. The findings show that a high level of industry skill intensity and a low level of competition from FIEs may foster in-house innovation in Chinese high-tech industries. Hence, the pattern of industry innovation activities is contingent on foreign competition and industry skill intensity. This not only confirms the importance of FIEs and skill intensity in indigenous innovation as found in existing studies (Blonigen and Taylor, 2000; Furman, et al., 2002; Marvel and Lumpkin, 2007; Marin and Bell, 2006; Reagans and Zuckerman, 2001), but also illuminates the inter-relationship between foreign competition and skill intensity, which has not been explored previously. Moreover, unlike more advanced economies in East Asia, such as Japan and South Korea, China has attracted a large amount of foreign direct investment and FIEs have been considered as the sources of new technology and innovation (Guo, 2008; Li, 2011; Li and Wu, 2010). This may be the reason that buy activities are dominant over make activities in the context of intensified foreign competition.

Our study contributes to the existing literature in several ways. First, we propose an integrated framework which embraces the industry-based view and the KBT. This integrated framework enables us to move beyond simply examining individual firms' strategic behavior and consider buy and make innovation activities in a broader and more complex industry setting, offering a better understanding of how industry contextual factors affect the pattern of innovation activities across high-tech industries. In particular, we focus on a large emerging economy where developing high-tech industries, enhancing innovation and upgrading innovation capabilities are a priority for government policy (Liu et al., 2011). Building upon prior studies (i.e. Guan and Chen, 2009; Guo, 2008; Hua and Mathews, 2008; Jung and Lee, 2010), our integrated framework helps to capture the driving forces of innovation activities from an industry perspective, adding a new dimension to the determinants of innovation activities in high-tech industries of an emerging economy.

Second, this study addresses an important gap in the existing literature where empirical evidence on the relationship between competitive dynamics, skill intensity and industry innovation activities is limited (Brandt and Thun, 2010; Jung and Lee, 2010). The findings offer valuable empirical evidence on what determines the intensity of make and buy activities in the first place. It also extends existing studies (e.g. Castellacci, 2007; Li and Vanhaverbeke, 2009) by examining the differential impact of foreign competition on make and buy innovation activities in the context of a large emerging economy. Hence, the findings help to provide new insights into how foreign competition influences the pattern of innovation activities.

Third, we have further investigated the interplay between foreign competition and skill intensity, and whether the interaction between foreign competition and skill intensity jointly affects the pattern of innovation activities across high-tech industries. The results from our research help to identify the condition under which foreign competition is more salient in shaping innovation activities, a relationship which has been underexplored in existing studies (Borensztein et al., 1998; Durham, 2004; Glass and Saggi, 2002; Liu and Wang, 2003). The findings enhance our understanding of the importance of domestic innovation infrastructure in the form of industry skill intensity. Skill intensity is a contingency factor which offsets the impact of foreign competition on innovation activities in high-tech industries. This finding shows that skill intensity not only affects buy and make activities directly, but also indirectly. Hence, our research broadens the impact of skilled personnel and provides a more complete account of innovation activities in an emerging economy.

This study has examined both favorable and unfavorable industry conditions for buy and make activities, and the findings have important policy implications. First, the findings from our research help policy makers understand the industry conditions under which different types of innovation activities occur. Increasing foreign competition may represent opportunities but will also bring new competitive pressures for domestic industries. Over the past decade, the Chinese government has implemented an industrial policy on promoting foreign direct investments and imports of foreign technology from developed countries (Guo, 2008; Liu et al., 2011). It is crucial that innovation policies reflect the changing industry environment in which FIEs have become a major competitive force. The governments of emerging economies could design appropriate policy to create an innovation-enhancing industry environment to respond to intensified foreign competition. Second, the positive impact of industry skill intensity on innovation activities indicates that the government should design a supportive policy which helps to enhance domestic skill intensity by allocating more resources to encourage domestic R&D activities and investment in R&D manpower, and in turn foster innovation within an industry. As shown in our research, without a sufficient number of scientists and engineers operating within local high-tech industries, the threat from FIEs to in-house innovation is significant. From the perspective of domestic innovation, an industry with a high level of skill intensity can withstand intensifying foreign competition through make activities. More importantly, given foreign competition, our findings emphasise that the industry skill intensity is an important ingredient in determining the intensity of buy and make activities. Finally, our findings imply that it may be crucial for the governments of emerging economies to adopt a combined technological development strategy for high-tech industries, which encourages indigenous firms to obtain cutting-edge international technology through outsourcing externally to catch-up with technological leaders, while simultaneously enhancing industry skill intensity and boosting in-house innovation, and in turn alleviate the competitive pressure from FIEs.

There are some limitations to this study. The study is limited to high-tech industries in the context of a single country. Future research could be extended to other industries and compare how firms in different industries undertake different innovation activities. In addition to the Chinese context, future studies should examine the impact of industry conditions on the pattern of innovation activities in other emerging economies, such as India, Brazil and Russia. This extension would enable researchers to compare whether the impact of industry characteristics is constrained by local institutions. Finally, while industry-level analysis helps to generate additional insights into different types of innovation activities, it should be noted that an industry-level analysis is based on an aggregation of individual firms in the industry and can only reveal a general pattern or trend of innovation activities taken by individual firms within the industry. Industry aggregation may obscure variations in the behavior of individual firms within an industry. In interpreting the results of the analysis this limitation should be borne in mind. Given that the impact of foreign competition and industrial contextual factors on the pattern of innovation activities at industry level has been largely under-explored in the context of emerging economies, we would submit that this limitation notwithstanding the proposed empirical analysis with industry data should be instructive. Future studies should use firm-level data to complement the current analysis.

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Table 1: Descriptive statistics and correlation matrix

	Mean	Std. Deviation	1	2	3	4	5	6
1 Buy	0.005	0.017	1.000					
2 Make	0.033	0.050	0.485	1.000				
3 Industry Concentration	2.673	5.358	0.084	0.439	1.000			
4 Foreign competition	0.491	0.306	-0.212	-0.186	0.321	1.000		
5 Skill intensity	0.057	0.045	0.183	0.594	0.393	0.124	1.000	
6 Capital intensity	0.419	0.312	0.478	0.261	-0.138	-0.510	0.009	1.000
7 Export intensity	0.171	0.165	-0.076	0.038	-0.027	0.155	0.109	-0.025

Appendix

A list of sub-sectors in Chinese high-tech industries

1. Chemical Pharmaceutical Products
2. Processing of Traditional Chinese Medicine
3. Biology Products
4. Aircraft
5. Spacecraft
6. Telecommunication Equipment
7. Radar and Peripheral Equipment
8. Broadcast and Television Equipment
9. Electronic Apparatus
10. Electronic Components
11. Household Audiovisual Equipment
12. Other electronic Equipment
13. Computers
14. Peripheral Equipment of Computers
15. Office equipment
16. Medical Equipment and Instruments
17. Instruments and Meters

Table 2: Results from the panel system equations

Make Equation	Coefficient (GMM) (Standard errors) Model 1	Coefficient (GMM) (Standard errors) Model 2
The intensity of foreign competition	-0.166***	-0.223***
	(0.024)	(0.048)
Skill intensity	0.163*	-0.473
	(0.082)	(0.175)
The intensity of foreign competition X Skill intensity		0.974*
		(0.496)
Control variables		
Industry concentration	0.004***	0.004***
	(0.0006)	(0.0003)
Export intensity	-0.045	0.041
	(0.037)	(0.023)
Capital Intensity	-0.026	-0.006
	(0.018)	(0.013)
Industry dummies	Included	Included
Year dummies	Included	included
Adjusted R^2	0.384	0.463
Buy Equation		
The intensity of foreign competition	0.007*	0.021***
	(0.003)	(0.005)
Skill intensity	0.018*	0.267***
	(0.009)	(0.076)
The intensity of foreign competition X Skill intensity		-0.356***
		(0.102)
Control variables		
Industry concentration	5.99E-05	0.0003*
	(0.0001)	(0.0001)
Export intensity	-0.005	-0.012***
	(0.003)	(0.003)
Capital Intensity	0.020***	0.018***
	(0.004)	(0.004)
Industry dummies	Included	Included
Year dummies	Included	included
Adjusted R^2	0.260	0.347
Observations	170	170

Note: †, *, **, and *** represent significance at the 0.1, 0.05, 0.01 and 0.001 levels, respectively.