When Do Latecomer Firms Undertake International Open Innovation: Evidence from China

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1. INTRODUCTION

By breaking through the boundary between a firm and its environment, Open Innovation (OI) "uses purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (Chesbrough, 2006). One of the important dimensions of OI is its international dimension. International Open Innovation (IOI) across borders can help countries and companies to address important global challenges and fundamental scientific issues, which are beyond the capabilities of an individual country (Cronin, Shaw and La Barre, 2003).

One of the effective strategies of OI is innovation collaboration, which facilitates outside-in and inside-out open innovations. Driven by increasing global competition and rapid technological changes, companies and governments regard innovation collaboration across countries as an important mechanism to strengthen their global competitiveness (Glänzel, 2001; Hwang, 2007; Wang, Huang, Wang, Lei, Zhu, Ren, and Jabeen,2014) and promote economic growth (Katz, & Martin, 1997; Sharma, & Thomas, 2008). The globalization of production has also motivated the business sector to internationalize their innovation activities. For the latecomer firms from emerging markets, although the majority of them may not be able to set up overseas R&D centers, most of them can and in fact have participated actively in international collaboration in innovation.

The surge of international research collaboration has attracted increasing interest in this area. In a recently published survey, Chen, Zhang, & Fu (2019) find that the work on international

research collaboration (IRC) has seen a "take-off" over the 2006-2015 period, addressing five distinctive intellectual areas: drivers of IRC, IRC patterns, IRC effects, IRC networks and IRC measurement. However, most of the literature is based on co-authorship analysis of joint publications and joint patents; little research examines innovation collaboration from a business perspective using firm-level data. Moreover, most of the studies focus on the early stage of the innovation chain, i.e., the research activities, while little attention has been paid to innovation collaboration between businesses and other partners, which may cover a wider range of innovation activities, especially innovations which relate to new product and process development.

While IOI has been adopted by both academia and industry, we still need to further probe the underlying conditions that motivate or discourage firms from engaging in IOI, and the factors influencing IOI's effectiveness (Vanhaverbeke, Chesbrough, & West, 2014; West, & Bogers, 2014; Wincent, Anokhin, & Boter, 2009). Moreover, despite all the benefits of IOI, firms have to cope with culture differences and geographic distances between different countries and overcome trade barriers when they undertake IOI activities. When do firms undertake international innovation cooperation? What are the main factors that prompt a firm to embark on international open innovation and engage with international innovation collaboration? R&D has two facets: it contributes to both knowledge creation and absorptive capacity of firms (Cohen, & Levinthal, 1990; Griffith, Redding, & Van Reenen, 2003). For firms that have a strong in-house R&D capacity, are they more or less likely to engage with international innovation collaboration? To what extent do firms' strategic orientations affect their engagement with international collaboration and open innovation? Is a firm's orientation towards technology leadership or new market creation more likely to motivate a firm to collaborate internationally in

innovation? To what extent do firms' international orientations impact on their decision to collaborate with foreign partners? Our understanding of firms' international innovation collaboration is limited.

This paper aims to fill this important gap in the literature by making a first attempt to examine the factors that affect a firm's engagement with international open innovation in an emerging economy using a survey database from China. Special focus is placed on analyzing how a firm's own R&D capacity and its strategic orientation may impact on the firm's international innovation collaboration. Given the Chinese government's transition of development strategy to the development of an innovation driven economy since 2006, its emphasis on innovation and rapid increase in R&D investment, China presents a good case for the study of international innovation collaboration in latecomer firms from the emerging economies. In addition to statistical analysis of the survey database, we also use qualitative evidence from some Chinese firms as examples to help us un-pack the estimated results from statistical models. The rest of the paper is organized as follows. Section 2 discusses the literature and the hypotheses. Section 3 introduces the data and methodology. Section 4 presents and analyzes the results. Section 5 concludes our findings.

2. LITERATURE AND HYPOTHESES

"Open innovation" has been widely accepted by innovative firms, which use a wide range of external partners and resources to help them achieve and sustain a better innovation performance (Chesbrough, 2003a). Previous studies suggest that antecedents to a firm's likelihood to undertake open innovation can be found at firm level (Chesbrough, 2003a), industry level (Chesbrough, 2006) and macro level (Chapman, Lucena, & Afcha, 2018; Lichtenthaler, &

Lichtenthaler, 2009). In this study, we focus on the impact of firm-level characteristics that shape a firm's strategy for international open innovation. Special focus is placed upon the IOI effect of a firm's R&D capacity, strategic orientation, and their international orientation, while controlling for their other characteristics such as prior experience, firm size, age, location, and ownership. Industry- and macro-level are included as control variables (Rothaermel, & Hess, 2007).

Why may firms' engagement with international open innovation be different from domestic open innovation? Using international innovation collaboration as an example, there are both substantial benefits from and risks associated with international cooperation in comparison to domestic collaboration, and these affect the motivations for latecomer firms to engage with international open innovation. Some risks and benefits are significantly different in comparison to domestic collaboration. On the one hand, due to great cultural and knowledge diversity, international collaboration is more likely to lead to innovation of greater novelty (Chen et al., 2019). For latecomer firms, collaboration with partners in industrialized or leading innovation countries may also facilitate greater learning and acquisition of advanced technology. On the other hand, the cultural, institutional and geographical distance between countries may also increase challenges to cross-country, cross-culture communication, management, and knowledge integration which are all key for innovation collaboration. Therefore, firms need strong motivations and capabilities to overcome these barriers and to engage with IOI. Hence, we focus on how the different levels of R&D capacity, strategic orientation in technological or market leadership, and in international orientation may affect a firm's engagement with IOI while also taking into consideration the impact of prior experience, firm size, firm age, foreign ownership, industry characteristics, and government support.

2.1 R&D capacity

R&D capabilities of firms have two sides (Aghion, & Howitt, 1998; Cohen, & Levinthal, 1989;; Griffith et al., 2003). One side is the widely acknowledged knowledge creation function; another is the role in learning and promoting ”absorptive capacity”, given the fact that innovation is cumulative and path-dependent. On the one hand, firms with strong R&D capacity may be more inclined to develop a new product or new process technology through in-house R&D. When a firm has strong R&D capacity and greater internal knowledge about a particular technology field, then 1) if the vision of this field is also known to other peer experts in the industry, this is likely to produce Rogers' "take-off" innovations (Rogers, 2010); 2) if the vision is unclear for peer experts in the industry while known to internal experts, there is a possibility for "old certainties" according to March (1991). In such a case, firms with strong internal R&D capacity and knowledge are more likely to develop the new product or process themselves. When a firm lacks internal knowledge of a field, and if this is a field that peer experts in the industry already have a good knowledge of, then this can offer "new possibilities" (March, 1991) for the firm. In such a situation, collaboration is preferred for this firm. If not, this can be Taleb's "black swan" area (Taleb, 2007). This then becomes a highly risky research area and may not be ideal for either in-house R&D or collaboration research. According to Lin, Yip, Tang, & Fu (2019), a leading Chinese MNE, Huawei Technologies Ltd., has developed a scope-weave-identify-modularize (SWIM) model to guide its collaborative innovation decision making process. Internal R&D capacity relative to external knowledge about the technology field has been taken into consideration when they decided which research questions should be brought forward for collaborative research. Huawei established a multi-tiered innovation organization, with R&D departments in business units focusing on questions with good internal knowledge,

and a Central Research department focusing on “Blind Spot” and “Unknown” questions in the “new possibility” and “black swan” areas. The strength of internal knowledge is also considered when they weave internal and external innovation activities. When a firm’s internal knowledge is strong enough to cover a new market opportunity, the company intends to give Full Cover to this field by means of internal R&D.

However, as discussed earlier, R&D also serve to strengthen a firm’s absorptive capacity. A firm’s capacity to absorb external knowledge will significantly shape its strategy for international openness in innovation. The concept of absorptive capacity was developed from previous research on organizational learning (Simon, 1969). Absorptive capacity has been proved to be an important component of innovative performance (Cohen, & Levinthal, 1990).

The R&D capacity of a firm can help it to appraise the value of new external information, assimilate it, and apply it to commercial ends (Li, Vanhaverbeke, & Schoenmakers, 2008). R&D intensity also helps firms to generate knowledge within themselves, e.g. new technology and new skills. The R&D intensity may improve the absorptive ability of a firm, which enables a firm to better adapt to the fast-developing environment. Although domestic collaborations are easier to establish given the similarity in cultural background and target markets, firms may acquire limited and less diverse forms of knowledge, as these are generated from the same information base. Thus, firms with higher level of R&D intensity are more willing to realize the internationalization of their R&D activities, and can benefit more from the diversified knowledge spillovers through collaborating with their foreign partners.

Given the above discussions, we therefore have two competing hypotheses.

H1a. Firms with higher R&D intensity are more likely to have greater international openness in innovation.

Hib. Firms with higher R&D intensity are less likely to collaborate in innovation and hence have lower international openness in innovation.

2.2 Innovation strategy

Innovation strategy mainly consists of the characteristics of organizational culture, the purpose of the innovation, as well as other choices that could have certain impacts on open innovation performance.

Technology-oriented radical innovations are characterized by high knowledge-intensity and high-input, with the prospective output of science-based technologies (Meyer-Krahmer, & Schmoch, 1998). Foreign suppliers, research institutes, and universities have traditionally been viewed as a support structure for radical innovations. These organizations provide the research results, well-trained experts, and knowledge in a specific field. The innovative firms which are proactive in acquiring new knowledge and using advanced technologies to develop their new applications or products (Cooper, 1984; Kanter, 1988) are more willing to collaborate with these suppliers and institutions.

Market-oriented radical innovation is consumption-based discontinuous product innovation which raises major concerns for direct market expansion (see Aboulnasr, Narasimhan, Blair, & Chandy, 2008). "Market" is a concept with rich connotations, including customers' needs (Von Hippel, 1986), buying habits, market growth, and the preferences in terms of features and product price (Cooper, 1983). A market-oriented firm can be defined as a firm with the ability and the willingness to recognize, analyze, understand, and satisfy customers' needs. Both the concept of customer orientation and also the concept of competitive orientation are included in

the literature on market orientation (Narver, & Slater, 1990). In order to respond to a competitor's action, a firm has to develop a great amount of new products so that it can sustain its competitive advantages. Therefore, a firm's market orientation is closely related to its competitors' innovation processes (Gatignon, Anderson, & Helsen, 1989; Robinson, & Pearce, 1988). Thus, we propose that:

H2a. Firms that have stronger orientation to technology-oriented radical innovation are more likely to be open to foreign suppliers, research institutes, and universities.
H2b. Firms that have stronger orientation to market-oriented radical innovation are more likely to be open to foreign customers and competitors.

2.3 International orientation

The international orientation may be interpreted as an indicator of strategic intent, and it may reflect the outcome of a strategy relevant to internationalization, or the extent of successful international collaboration (Filatotchev et al., 2001; Hamel, & Prahalad, 1989).

Firms which focus on exporting goods and expanding in international markets have to consider how the selected new products contribute to profitable growth at home as well as abroad. The new ideas, products, services, or business models of those firms may need to be adjusted, so that they could be successfully introduced not only in the domestic markets but also in the international markets. Testing the prototype in different countries requires thinking and acting internationally.

Also, firms that choose to export their products are under pressure to increase their innovative capabilities, as they have to consider both local and international competitors in the market. Prior studies suggest that irreplaceable technologies help global firms to create

sustainable competitive advantages (Almor, Hashai, & Hirsch, 2006; Bell, 1995; Hashai, & Almor, 2004; Jones, 1999; Stray, Bridgewater, & Murray, 2001). If they want to possess the core capabilities for successful entry into the international market, they might need to rely on collaborations with foreign firms in developing new technologies and products. Previous research in the Chinese semiconductor and automotive industries has found that export-oriented firms tend to be more open and innovative, compared to firms which focus largely on the domestic Chinese market (Fu, Li, Xiong, & Chesbrough, 2014; Fu, 2015). Hence, we propose that:

H3. Firms with greater international orientation (export exposure) are more likely to have greater international openness in innovation.

3. DATA AND METHODS

This study uses data from the 2008 Chinese national innovation survey which contains data on manufacturing firms' international OI activities between 2005 and 2007. Admittedly the data is somewhat outdated. However, it provides a suitable case for us to examine the determinants that drive latecomer firms to collaborate with international players. We believe that this data could still represent valuable findings of international open innovation in developing countries, and other useful implications for policy makers and business leaders in other countries, because during this time period, China has undergone a profound transformation aimed at becoming an innovation-oriented country. The Chinese government placed innovation at the center of the country's development strategy for the first time in 2006 (Fu, 2015). The "independent innovation" policy was introduced to strengthen Chinese firms' indigenous innovation capacity.

Government R&D expenditure in China started its exponential growth in 2006. In addition, a large number of policies to promote open innovation were being implemented during that time. For example, in the year 2005, the Central Economic Working Conference (CEWC) encouraged Chinese firms to actively implement a mutually beneficial strategy to further enhance the level of opening up to world. In 2006, CEWC further issued policy documents encouraging Chinese firms to improve their capability of open innovation. In 2007, the Conference again called on firms to be more open for industrial upgrading. Thus, the sampled period witnessed a special period in a large emerging economy which started to place innovation at the center of its development strategy, encouraging open innovation while investing heavily to support ”independent innovation” at the same time. Therefore, analysis using this data could still provide valuable insights of firms' behavior in international open innovation in a developing emerging economy, and offer valuable lessons for many other developing countries.

The survey was carried out by the National Statistical Bureau, with the assistance from Tsinghua University who designed the questionnaire, which highly resembles the European Community Innovation Survey (CIS). This survey covers 42 cities of China, not only in inland regions but also in coastal regions. We received a total of 1,408 valid responses, with a response rate of 83.6%. All different major ownership types of firms that exist in China are included in this sample. The data consists of 53% share-holding and limited liability companies, 30% foreign invested firms, 9% state or collectively owned enterprises, and 7% privately owned firms. About 50% and 17.5% of the firms in the sample are medium-size and large-size firms, respectively.

Table 1 demonstrates a breakdown of the sample firms according to their ownership characteristics. Table 2 shows the collaboration strategies for the different types of collaborators. About 48.2% of the selected firms are those claiming to have conducted collaborative innovation

from 2005 to 2007. As the data shows, private firms are more likely to collaborate with other firms (32.0% vs. 28.8%) while more foreign firms tend not to do so (11.6% vs. 18.8%). For state-owned firms, there is no significant difference (4.6% vs. 4.2%). Correlations between all the variables are shown in Table 3. The variance inflation factors (VIFs) for all the variables were less than 1.86 and below the recommended value (i.e., 10) as suggested by Chatterjee and Price (1991). Thus, no collinearity problems existed for these variables.

INSERT TABLES 1 & 2 HERE

3.1 Measurement

International collaboration*:* In this study, we assume that international collaboration equals 1 if a firm participates in any innovation activities with another organization in a foreign country, and 0 otherwise. We distinguish between firms that cooperate with other domestic organizations, and firms that collaborate with foreign partners. Then we count the number of international collaborations as well as the total number of all domestic and foreign collaborations. Thus, the international openness in innovation can be measured as:

$$\frac{Number\ of\ international\ collaborations}{Total\ number\ of\ collaborations}$$

Formally this can be expressed as:

$$IOI = \frac{\sum_i^n ICO}{\sum_i^n CO}$$

where IOI is international open innovation, ICO international collaborations, and CO is collaborations. The IOI index takes values from 0 (no international collaborations) to 1 (only international collaborations) as a ratio of openness to international collaborations.

Admittedly, while this measurement has the advantage of reflecting the intensity of a firm's international openness in innovation, it also bears some limitation in that it does not capture the scale of international innovation collaboration that a firm may engage with. In recognition of these advantages and limitations of the IOI measurement, we also use the total number of international collaborations as an alternative measurement, and relevant estimations are reported for a robustness check.

R&D capacity*:* R&D investment is one of the major factors that strongly influence a firm's innovative capacity. Firms that invest heavily in R&D activities have a greater chance to achieve technology breakthroughs (O'Brien, 2003). We therefore measure it by taking the logarithm of a firm's intra- and extra-mural R&D investment in 2007.

Technology-oriented radical innovation*:* Technology-oriented radical innovation is defined according to two indicators from the questionnaire: firstly, whether a firm has reported "Mainly engage with basic research in its R&D positioning" as its main innovation strategy in the past three years; secondly, whether a firm has produced new-to-the-world innovation in the past three years. Therefore, "technology-oriented radical innovation" is represented by a dummy variable which equals 1 if a firm has produced new-to-the-world innovation and at the same time "mainly engaged with basic research as its main R&D strategy", and 0 for the other scenarios.

Admittedly, there are some limitations of using this variable as a proxy of technology-oriented radical innovation. Firstly, radical innovation involves a fundamental improvement over the old technology, leads to new products that are difficult to replace with substitute technology, and brings substantial change in consumption preferences in the market (Zhou & Li, 2012). Therefore, whether a firm has new-to-the-world innovation is not a perfect measure of radical

innovation. The way this dummy variable is created makes assumptions that simplify the complexity of a multi-purpose situation.

Market-oriented radical innovation*:* Market-oriented radical innovation is defined based on two indicators from the questionnaire: firstly, whether a firm has reported ”Prioritize entering new industry rather than grow its current market in R&D direction selection” as its main innovation strategy in the past three years; secondly, whether a firm has produced new-to-the-world innovation in the past three years. Therefore, we proxy ”market-oriented radical innovation” by a dummy variable which equals 1 if a firm has produced new-to-the-world innovation and at the same time ”prioritize entering new industry as its main innovation strategy”, and 0 for the other scenarios.

International orientation*:* We measure the firm’s international orientation by the overall domestic export value which is generated by the export products of a firm. This is believed to be a best indicator of firm’s exports. This measurement is consistent with most previous studies.

The control variables include a group of firm characteristics that will affect a firm’s collaborative innovation partner selection. These characteristics include:

- *Previous experience:* Previous experience of domestic collaboration may increase the likelihood of both sides in different places to work together successfully (Cummings & Kiesler, 2008). We measure this by a firm’s total collaboration value.

- *Firm size:* It is measured by the total number of employees of a firm. Larger firms always have a greater range of market partners through which to look for opportunities for international collaboration.
- *Firm age:* As firm age increases, firms may have accumulated more experience and gained a larger knowledge base, which are more likely to influence the IOI.
- *Geographic location:* Firms in different regions are normally influenced by the openness of the region's economy, and the region's international links with foreign players. A vector of regional dummies is used to represent the impact of a firm's innovation environment.
- *Policy:* We use governmental funding received by the firm as a measurement of policy. The government funding may include support that is related to R&D expenditures as well as R&D tax credits. Firms which receive government support may have different engagements with international innovation collaboration depending on the objectives of the grant.
- *Industry specific characteristics:* Since technology dynamics may vary across sectors, we include a dummy variable that equals 1 for high-technology industries and 0 otherwise, to control for these differences.
- *Uncertainty:* Following the measurement of *task uncertainty* in the literature by product novelty, project complexity, and extent of design changes (e.g., Lee & Veloso, 2008; Pich, Loch, & Meyer, 2002; Takeishi, 2002;), we measure uncertainty in innovation by a weighted index of a firm's rating of the following four factors: (1) whether economic risks in innovation are too big; (2) whether the investment required by technology innovation is too much; (3) whether the firm lacks sufficient accumulated technology; and (4) whether the firm lacks relevant technological information for innovation. An equal weight is assigned to each of these factors.

4. RESULTS

As only firms that decided to engage with collaborative innovation will report total number of collaborations and the number of international collaborations, we used Heckman's (1976) two-step model for the estimation. An initial binary model estimates the probability of a firm undertaking collaboration in the first equation, and a second stage OLS (Ordinary Least Square) equation, of which IOI is the dependent variable, contains a selection correction term derived from the first equation, and captures the determinants of IOI. Table 4 reports the estimated results using Heckman's model.

INSERT TABLE 4 HERE

4.1 R&D capacity

To test Hypotheses 1, we first regress firms' international openness in innovation (IOI) against the firm's R&D capacity, and gradually enter other explanatory variables and control variables for robustness check. The estimated coefficient is negative and is statistically significant at the 5% level across all six models, which supports our Hypothesis 1b, and is opposite to Hypothesis 1a. In other words, although R&D capacity also reflects a strong absorptive capacity, our evidence supports Hypothesis 1b that Chinese firms with a strong in-house R&D capacity are less likely to engage with international open innovation during the sample period.

As Chesbrough (2003b) suggests, firms that are "too focused internally" are "prone to miss a number of opportunities." Innovative firms which spend too much on internal R&D activities may have limited resources to draw on knowledge from a wide range of external sources. This is

likely due to the firm's own technology capabilities that enable them to create outstanding products and provide them with an irreplaceable market position (Lawson & Samson, 2001). Thus, they are less motivated to search for foreign collaborators or match others; instead, they seek to be "the best of the best" themselves. Moreover, compared with firms with a high level of R&D intensity, their foreign partners may benefit more from the diversified knowledge spillovers through collaborating. Thus, it may weaken the motivation of firms with higher level of R&D intensity to realize the internationalization of their R&D activities. The findings are also consistent with Huawei's SCOPE decision-making principle, when the strength of internal knowledge of a particular technology area is taken into account (Lin et al., 2019).

4.2 Technology-oriented radical innovation

Next we included technology-oriented radical innovation in Models 5 and 6. Although many firms in the high-technology industry are born with an international orientation (Filatotchev, Liu, Buck, & Wright, 2009), from column (5) it can be seen that the coefficient of technology orientation exhibits a positive but insignificant effect on international openness in innovation, which provides no evidence in support of Hypothesis 2a.

This conclusion is consistent with Gatignon and Xuereb's. (1997) findings that "the greater the firm's technology orientation, the greater the product advantage provided by these innovations, which are more radical and less similar to the competitors' products". Therefore, firms with strong technology orientation would prefer to develop in-house innovation, because when they are willing to develop something new to the world, they cannot wait for a long time until they find a suitable foreign partner. All they need is to speed up the process to beat the competition in the market.

4.3 Market-oriented radical innovation

Columns (5) and (6) also report the role of market-oriented radical innovation. There is a direct positive relationship between market-oriented radical innovation and international openness in innovation ($\beta = 0.099$, $p < 0.05$), which supports Hypothesis 2b.

The reason why market-oriented innovation acted as a more crucial determinant than technology-oriented innovation in IOI can be summarized as follows. First of all, firms need to gain knowledge from their foreign partners about the target buyers in a certain market. With the help of international collaboration, they may be able to identify, analyze, understand, and answer the user's needs, so that they could continuously create superior value for them. Secondly, these two strategic orientations may occur at different stages of innovation. As Lee, Park, Yoon, & Park, (2010) suggested, open innovation activities are more effective at later innovation stages when the firms already have something to provide and prove themselves in the market. During the early stage of innovation, firms have to search in great depth to find suitable and trustworthy partners with whom to conduct the R&D activities, which is a very time-consuming process. However, Laursen, and Salter (2006) found that in the latter stages of innovation, firms can benefit from scanning across a wider range of channels to commercialize their products. That may explain why the market-oriented innovation is much closer to international openness in innovation than is technology-oriented innovation.

4.4 International orientation

We ran logistic regression and included firm exports as a dummy variable in Model 5. From column (5), we observe that a firm's exports appear to be significantly associated with international openness in innovation ($\beta = 0.099$, $p < 0.01$). The results indicate that Hypothesis 3 is supported.

The finding is consistent with evidence from Gassmann (2006), which shows that open innovation is more appropriate in contexts of globalization. Grossman, and Helpman (1991) found that international trade allows a bidirectional information exchange across countries. This is also found in Chinese firms' innovation through its internationalization (Fu, 2015; Yip and McKern, 2016). Competing in overseas markets facilitates exporting firms to learn indirectly from foreign agents or learn directly from their customers (Salomon & Shaver, 2005). The knowledge exchanged from the foreign markets helps firms to learn by exporting. Thus, it becomes easier for firms with a higher degree of globalization to communicate with foreign partners, as they have previous experience of participating in international trade. The smoother communications and better mutual understanding help both sides to build trust. As a result, they are more likely to conduct innovation activities and develop new products together.

Admittedly, there is a possibility of a two-way relationship between international orientation and international openness in innovation (in particular international collaboration). Therefore, there are some ambiguities in the directionality. Therefore, caution should be taken in drawing conclusions. Future research with suitable data is needed to fully explore the direction of the causality between these two factors.

With regard to the estimated results of the other control variables, the estimated results reported in Models (2) and (6) suggest that previous experience appears to be a positive and significant determinant in firm's choice to collaborate with foreign partners. The estimated coefficients are around 0.029, and are statistically significant at the 1% level across all models, suggesting the robustness of the results.

From column (3), we can see that being in the high-technology sector has a positive impact on international openness in innovation ($\beta = 0.043$, $p < 0.1$). The results are also robust across all model specifications, suggesting that the firms in the high-technology sector are more likely to collaborate with a foreign partner and have a higher degree of international openness in innovation. These dynamic high-technology industries include consumer electronics (Christensen, Olesen, & Kjær, 2005), automotive (Ili, Albers, & Miller, 2010), biotechnology (Fetterhoff, & Voelkel, 2006), etc. The results are likely to be due to the characteristics of the high-tech industry, such as short product life cycle, fierce market competition, and great technology difficulties. Most firms in these industries are interested in cooperating with foreign firms, for the purpose of reducing costs and uncertainties, as well as expanding their international market. Also, unlike military industries, most products in these industries are designed for the purpose of making a profit. Firms in these areas can cooperate across countries without too much political concern. Thus, international openness in innovation is more likely to be achieved in high-tech industries. Given Chinese government policies towards greater indigenous innovation during the sample period, the empirical pattern we find here is likely to intensify.

Firm size and firm age are also confirmed to have some significant impacts on firms' possibility to collaborate with other organizations. Smaller firms are significantly less likely to engage with international innovation collaboration in comparison to large Chinese firms. Younger firms are more likely to engage with international innovation collaboration than older firms. Firms located in coastal regions have significantly higher international openness to innovation. Foreign invested firms also have great international openness to innovation. The estimated coefficients are around 0.15 suggesting that IOI of foreign invested firms is 0.15 units higher than that of domestic Chinese firms, on average, during the sample period.

Finally, we found a negative correlation between policy and international openness in innovation ($\beta = -0.076$, $p < 0.01$). As Mani (2004) argued, the ultimate goal of innovation policy was to promote local development of science and technology. Thus, in most countries, government funds and various policies have been put into effect by the country to encourage firms to conduct in-house R&D projects.

4.5 Robustness tests

We carried out several robustness tests using different estimation methods. Table 5 reports the OLS model estimate of the number of domestic collaborations and the number of international collaborations. According to the estimated results reported in Table 5, although R&D capacity and international orientation have similar impact on a firm's number of international and domestic collaborations, market-orientated radical innovation, industry dynamics proxied by high-technology industry dummy, and uncertainty all have different impacts on international versus domestic innovation collaborations. In particular, previous experience in collaboration has a significantly different impact on a firm's domestic and international collaboration numbers. Overall, evidence from this exercise provides further evidence suggesting that the factors that affect a firm's degree of international openness in innovation are different from those determining its domestic innovation openness.

INSERT TABLE 5 HERE

Further robustness checks are reported in Table 6. Part A of Table 6 reports the results of a robustness test using the OLS model of which IOI is the dependent variable. The results are broadly consistent with the Heckman models, especially regarding the effect of policy,

international orientation and sector dynamics, which all remain at the same significance level. The estimated coefficients of R&D intensity and firms' market-oriented radical innovation are more statistically significant than for the Heckman model, but lead to the same conclusion. Moreover, previous experience and uncertainty become statistically significant, though they were insignificant before. These facts suggest that most of our original hypotheses have been supported.

The results of robustness tests using a Tobit model are reported in Part B of Table 6, also with IOI as the dependent variable. Previous experience and uncertainty become significant contributors to the choice of cooperation; R&D intensity is not statistically significant although the negative result stays the same as the Heckman model. International orientation again contributes significantly to international open innovation. Market-oriented radical innovation and policy are also statistically significant. To sum up, the robustness tests suggest that our results are mostly robust. Figure 1 summarizes our estimation findings.

Table 6. Robustness test: Determinants of international OI estimated using OLS and Tobit models

INSERT TABLE 6 HERE

INSERT FIGURE 1 HERE

5. CONCLUSIONS AND DISCUSSIONS

This study examines five important determinants which may influence the likelihood of firms' international open innovation. While the consequences of acquiring external resources for

a firm's innovation process have been well researched, we still have little insight into what happens inside a firm that would strengthen or weaken its ability to enter the OI process (Tucci, Chesbrough, Piller, & West, 2016). It supplements previous studies and helps both managers and policy-makers to understand how a wide set of incentives and motivations contribute to a firm's IOI process.

From the firm level, we find that previous experience, market oriented radical innovation, and international orientation are important for building international collaboration effectively. According to our research, if firms want to be more open in the international innovation process, they need to gain more domestic open innovation experience, as well as adjust their strategy to be more market-oriented and try to promote their product exports. These actions may help firms to deal with the substantial differences in market demand, organizational culture, and technical conditions between partners' countries.

We also find that some determinants of IOI in our original hypotheses have opposite effects and lead to in-house innovation. Our results do not support the hypothesis that R&D intensity and technology oriented radical innovation can work as the trigger for international partnerships that can enhance value creation (Enkel, 2010). This finding provides us with a point of view that firms spending too much on internal R&D activities may miss the opportunity to gain knowledge and experience from various external sources. In other words, technological-oriented radical innovation does not motivate Chinese firms to collaborate with foreign partners during the 2005-2007 sample period. They chose to carry out R&D in-house to purse indigenous innovation as encouraged by government policy at that time. This may also due to the internal power balance and pushed by the R&D department. This is consistent with the in-house R&D versus collaboration decision making consideration found in some Chinese MNEs (Lin, et al., 2019) and

findings from Cassiman and Valentini (2016) that inbound and outbound open innovations empirically do not show complementarity in creating more innovations. Thus, managers in firms with a higher level of R&D capabilities should find a way to open their innovation system and build connections with external resources.

From the industry level, sector dynamics have been found to be important for building international collaboration effectively. Firms in high-tech industries may find it difficult to deal with the uncertainty and manage the innovation processes. Our study provides suggestions for managers to pursue new opportunities and help firms to get used to the dynamic and uncertain environment.

From the macro level, it can be seen that government policy does not appear to be as effective as expected in encouraging international collaborations, which has important policy-related implications. Chinese firms need to conduct IOI for international market expansion. The results bring insights that the policy-makers need to support firms' IOI activities through more channels or set up some special funds to encourage the information or resource exchanges between China and other countries. Moreover, the policy-makers should open up the production and trade regimes so that knowledge can be easily imported from different countries.

This paper also raises several recommendations for further research in this area. Firstly, all the samples used in this paper were Chinese manufacturing firms during a particular time period of economic catchup, when policies strongly encouraged firms to be more market-oriented. Nowadays, firms are becoming more technology-oriented and give a priority to "innovate in China". Despite the fact that the period of time we chose to study is an important and fast-developing period in China, which is worthy of studying, more work needs to be done to fully understand the whole process of IOI in the new era. Future research should examine this issue by

collecting data over a longer period, and we should enhance our understanding of the way firms learn, change, and perform over time. Secondly, with the enormous changes in the international situation, manufacturing firms in developing countries are under tremendous pressure to survive, so further research is needed to determine how these organizations can become more open to innovation (Drejer, 2001). To note, however, although the majority of the firms in the sample are relatively young and of small and medium size, and in general the Chinese firms in the sample can be regarded as latecomers during the sample period, admittedly there is still heterogeneity in the sampled firms. Therefore, caution should be taken on the generalizability of the findings with regard to the latecomers.

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