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When Do Firms Undertake International Open Innovation?

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Abstract: In this study, we examine the characteristics of firms and their surrounding environment and investigates their likelihood to develop the international openness in innovation. Our survey contains data on 1,408 manufacturing firms' in China which conduct open innovation activities, and the research span extends from 2005 through 2007. Using the Heckman model, we examine the factors which influence the firms to undertake international open innovation (OI), such as the dynamic environment, the uncertainty faced by firms, the different strategies of firms and government support received by firms. It turns out that there is a direct positive relationship between international orientation and international OI. The technology dynamics and endogenous uncertainty also significantly explains the improvements in firms' international open innovation performance. Discussions and analyses are given to these findings. All these findings extend the literature in organizational learning and supplement the resource-based view with the external environment. Both managerial and academic implications are presented for further study.

Key word: International open innovation; capabilities; uncertainty and dynamics; strategy; political support

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I. Introduction

Open innovation (OI), which enables the innovation moves easily between firms and break through the boundary between a firm and its surrounding environment, has been defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (Chesbrough, 2006a). The OI concept was also supplemented by the notion of open business models (OBMs), that is, a firm's use of the assets of external partners to develop its business model (Chesbrough, 2006b). This strategy is orthogonal to the use of international OI, in that firms can combine OBMs with closed innovation strategies and all possible combinations (Vanhaverbeke and Chesbrough, 2014).

In the literature, many reasons have been reported for the fast development of international OI. New technologies provide people with new ways to collaborate across geographical distances and escape the limitations. With the spread of internet, the cost of communication has been reduced sharply, while the efficiency of communication has been increased sharply. With the help of the modern means of transport, the movement of people has become much easier and cheaper, which encourage the rapid spread of knowledge. It becomes much easier for firms to realize the value of the internationalization of R&D and the globalization of production.

There is no doubt that international knowledge and markets are important factors for firms to success, especially for emerging and developing countries. A fundamental shift is taking place in the geography of innovation. As many emerging countries is growing rapidly, the global balance of innovation is being changed by new collaboration patterns. In order to avoid being left behind, the economic superpowers need to step out of their comfort zones and build partnerships with the new players in this new landscape.

The factors which influence the likelihood of firms to undertake international OI are examined by this paper. The questions asked are: When do firms undertake international OI? Will the dynamic of industries matter for the choice of international OI? Is the uncertainty faced by firms influential on the international OI? Will the different strategies of firms lead them to corporate with different kind of partners? Will the government support play an important role to encourage firms to undertake international OI?

In spite of all the benefits of OI, firms have to cope with the culture differences, distances in geography and overcome the language barriers when they undertake OI activities. Different countries have different degrees of openness, different development level and knowledge bases, and different market demand and financial resource. Sometimes poor communications leading to confusion and misunderstandings. These would affect the partner's compatibility in objectives, values and capabilities, and it may become difficult for them to find opportunities for cooperation and trust (Argyle, 1991; Johnson and Johnson, 1989). How does the capability in knowledge integration and co-production be influenced by these factors? Up until now, there has not been a theoretically satisfying explication of the underlying mechanisms contributing to OI. (Tucci et al, 2016)

Meanwhile, most of the literature about firm's OI concentrate on the impacts of OI, but the determinants and the antecedents of OI have not been studied thoroughly. OI

requires firms to make new decisions and choose new strategies in conducting innovation activities. When, how, with whom, with what kind of aims, and in what way should they collaborate with outside partners? As far as we know, these problems are still unknown yet. Our research tries to fill in these gaps in the literature by examining the characteristics of firms and its likelihood to develop the international openness in innovation.

Although there is a growing literature on OI, most of them are about the research collaboration which mainly measured by paper and patents. There is a lack of evidence about the topic of problems exist during the process of firms' international collaboration. The 2008 Chinese national innovation survey of 1,408 manufacturing firms in China is used in this research, which covers 42 cities in both the inland and coastal regions. The results of our research not only provide strong empirical support for the theory of OI, but also provide guidance to the strategies of firms.

The main structure of the paper is organized as follows. Section 2 discusses the literature and the hypotheses. Section 3 discusses the data and methodology. Section 4 presents and analyze the results. Section 5 concludes.

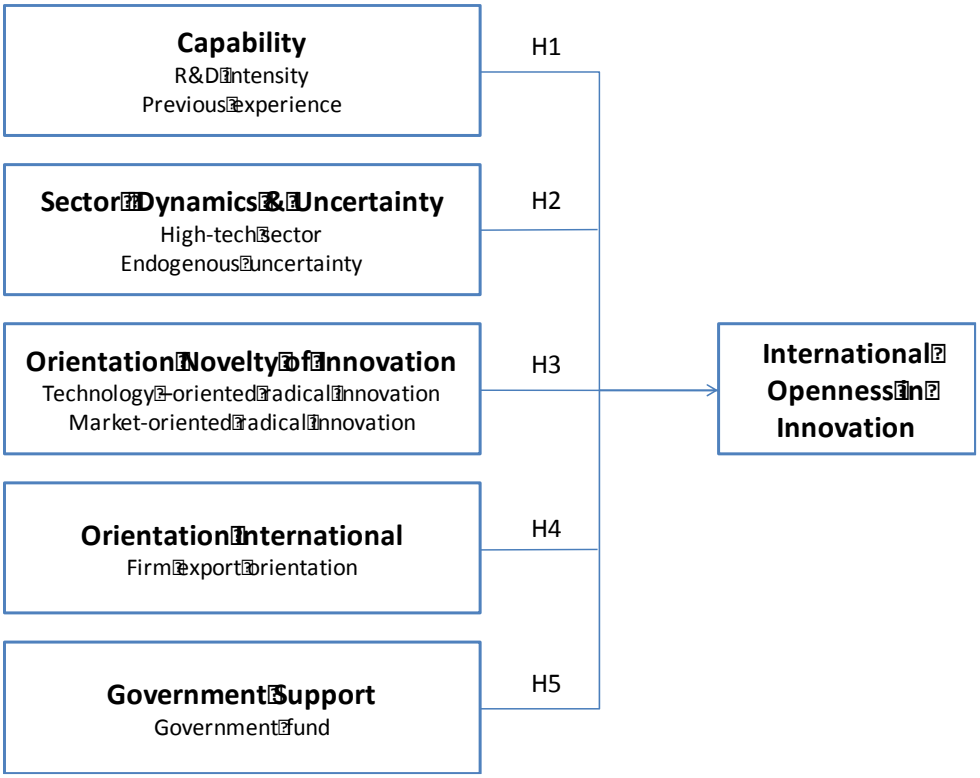
II. Literature and Hypotheses

It has been widely discussed that how firms can benefit from collaborating with others. An OI starts with simple outsourcing deals with contract service organizations to reduce overcapacity and risks, or to cut costs through an increased labor division due to globalization.

Chesbrough (2003a) suggests that an 'open innovation' model has been accepted by many innovative firms, which have a wide range of external partners and resources to help them achieve and sustain a better innovation performance. These external actors provide opportunities to combine previous disconnected knowledge base and capabilities together, and encourage firms to invest in internal R&D activities (Fleming, 2001; Hargadon and Sutton, 1997; Schumpeter, 1942). This may lead to successful commercialization of new products, and help firms to conduct international openness in innovation.

Open innovation model can be decomposed into four constituent dimensions: "value creation and capturing via the business model, transactions / networks with innovation partners, capabilities or competencies, and coping with technological and market uncertainty which is embedded in the funnel concept" (Chesbrough, 2003). While OI has been well adopted by both academia and industry, what is needed now is to go beyond these questions to probe the underlying conditions that motivate or discourage firms from engaging in OI, and what factors influence OI's effectiveness (Wincent et al., 2009; Vanhaverbeke et al., 2014; West and Bogers, 2014) are still unclear.

Figure 1 The determinants of International Openness in Innovation



Capabilities

In this paper, we link empirically the firm's ability to explore external knowledge to international openness in innovation. We believe that the R&D intensity will increase the absorptive capacity which helps a firm to evaluate the value of new, external information, assimilate it, and apply it to commercial ends. The concept of absorptive capacity developed from previous research on organizational learning (Simon, 1969). A large amount of time and effort has to be devoted to build up an understanding of the norms, habits, and routines of different external knowledge channels. It has been argued that this ability is an important component of innovative performance (Cohen and Levinthal, 1990: 128).

The R&D intensity will also help to generate knowledge inside the firm, e.g. new technology resulting from R&D activities (Smith et al., 2005). Thus, the innovative ability of a firm will be increased. In order to adapt to change and react to environment, those organizations that invest more in R&D activities may have a greater ability to create new products. Thus, it may increase the probability for foreign firms to cooperate with them.

Teece (1977) has considered the substantial cost of knowledge transfer between alliances, which includes the cost in teaching, demonstrating and building personal connections. These costs would be reduced with continuous transfers and previous experience (Arrow, 1962), and the possibilities of susceptibility to opportunistic behavior would reduce at the same time (Mody, 1993; Dodgson, 1993).

In a capability-based view of open innovation, which includes multiple interactions with a firm's environment (Chesbrough, 2003), we believe that the acquisition of resources from external environment results from a prolonged process of investment and knowledge accumulation. We also believe that a firm with experience in domestic collaboration has learned how to deal with partners in a complicated context. This kind of learning decreases the uncertainties related to managing inter-organizational partnerships and, therefore, increases the degree of international openness in innovation.

Since absorptive capacity and domestic openness are closely linked to international openness in innovation, we expect—

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

H1b. Firms with more previous experience are more likely to have greater international openness in innovation.

Uncertainty, dynamics

In high technology industries, the rapid development of new products may increase the likelihood of firms' survival, thus it is viewed as a crucial determinant of success (Deeds, D. L., DeCarolis, D., & Coombs, J. 2000). The innovation process has become increasingly open in high-technology industries with a great technology dynamics. Nowadays, as new technology is becoming more and more complex, even large firms cannot afford to develop a new product without collaborating with others. Firms collaborate with partners all over the world, not only to share R&D costs and access to resources through R&D's internationalization, but also to create new ideas and products in order to face the intense global competition. Thus, the establishment of alliances and R&D partnerships have become a strong trend for firms to survive in the dynamic environment (Hagedoorn & Duyster, 2002).

From the perspective of resource-based theory, the dynamic capabilities of these firms accumulate and develop over time. Both the organizational learning and industry opportunities help to accumulate these capabilities (Teece, Pisano & Schuen, 1992). Drawing on Huber's (1991) work, organizational learning is defined as the development of new knowledge or insights that have the potential to influence behavior. In order to improve firm's performance, the capabilities which embedded in high technology industries should be as dynamic as the environment around them (Deeds, DeCarolis & Coombs, 2000).

Thus, it is obvious that international OI is mainly conducted in industries with great technology dynamics. The pioneering industries such as telecommunications, electronics,

computer science, and biotechnology have widely accepted the concept of open innovation (Chesbrough, 2003). In order to meet the rapidly changing customer requirements in these industries with dynamic environments, firms must try to pursue new opportunities that contain high levels of uncertainty

Therefore, we have the following propositions:

H2a. Firms in high-tech industries are more likely to have greater international openness in innovation.

Endogenous uncertainty may be due to an inability to grasp the whole structure of key knowledge for successful R&D, or how much time, effort, and resources will be required to accomplish a project (Folta, 1998). It can be reduced by the effort of any single firm. Firms might experience endogenous uncertainty when a prospective radical innovation refers to plenty of technical difficulties and has the possibility of innovation failure. The higher the likelihood of technical failure and the costs associated with success, the higher the endogenous uncertainty (McGrath, 1997). Thus, firms may not scan for these breakout technologies when they find it difficult for them to manage the processes and deal with the high-risk opportunities.

To reduce the endogenous uncertainty, firms may choose to minimize risk by investing in technology that has been proven in other products, instead of looking outside for 'new to the world' technologies. As learning new technology from outside requires great internal efforts which can interact effectively with many different partners across the firms, firms may not choose to collaborate with foreign firms when they are not able to handle all the difficulties.

Therefore, we have the following propositions:

H2b. Firms that face greater endogenous uncertainty may have low openness in international open innovation.

Strategy

Strategy characteristics mainly consist of organizational culture, purpose of the innovation strategy, incumbents versus newcomers, as well as other purposeful acts that could have some impacts on open innovation performance. We believe that international orientation may be interpreted as an indicator of strategic intent, and it may reflect the outcome, or extent of success, of a strategy relevant to internationalization (Hamel & Prahalad, 1989; Filatotchev, Dyomina, Wright & Buck, 2001).

Prior studies suggest that irreplaceable technologies help global firms to create sustainable competitive advantages (Almor, 2006; Bell, 1995; Hashai & Almor, 2004; Jones, 1999, 2001; Stray, Bridgewater & Murray, 2001). Based on resource-based view of

the enterprise, we believe that the international orientation of firms not only depend on the investment they spend on R&D activities, but also on the human capital of entrepreneurs, such as global social network, previous experience, and technology transfers from other countries.

In addition, from the knowledge-based view (KBV) of the firm, most of the new international ventures which have a small size, resource constraints, short product life cycle are knowledge-intensive organizations (Zahra et al., 2000). Facing intense market competition, they have to deal with the pressure to learn fast to survive and persuade their leaders to build external connections to resources in a global network.

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). The foreign supplier, research institutes and universities have traditionally been viewed as a support structure for radical innovations, providing research results, trained persons, and knowledge to industry. The innovative firms which are proactive in acquiring new knowledge, using advanced technologies in the development of their new applications or products (Cooper, 1984, Kanter, 1988) are willing to open to these suppliers and institutions.

Market-oriented radical innovation is consumption-based discontinuous product innovation with major concerns about direct market expansion (see Aboulnasr et al., 2008). The "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, to analyze, to understand, and to satisfy customers' needs. Not only the concept of customer orientation but also the concept of competitive orientation is included in the literature on market orientation (Narver & Slater, 1990). In order to response to a competitor's action, a firm has to develop a great deal of new products so that it is able to sustain the competitive advantage. In this way, a firm is closely related to its competitors' innovation processes (Gatignon, Anderson & Helsen, 1989, Robinson, 1988).

Thus, we propose that:

H3a. Firms that have stronger orientation to technology oriented radical innovation are more likely to open to foreign supplier, and research institutes and universities.

H3b. Firms that have stronger orientation to market oriented radical innovation are more likely to open to foreign customers and competitors.

International orientation

The 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. Those firms may need to adjust their new idea, products, service or business model so that it can successfully be introduced not only in the domestic markets but also in the international markets. Testing the prototype in different countries requires them to think and act internationally or even globally.

Also, those firms choose to export their products are under the pressure to increase their innovative capabilities, as they have to consider both local competitors and potential international competitors in the market. If they want to have the core capabilities which allow for a successful entry in the international market, they may be glad to collaborate with foreign firms in new technologies and products development.

Hence, we propose:
H4. Firms with great international orientation (export exposure) are more likely to have greater international openness in innovation.

Political support

The purpose of our study is to know how government intervention exerts its influence on innovation. In other words, we would like to figure out whether the firms which receive public funding could have greater openness in international innovation than those that do not get any government support for innovation.

There is no doubt that the role of government is to promote openness in innovation. First of all, the government could support the firms by opening up their production and trade regimes so that knowledge can be easily imported from developed countries. Moreover, the government support can also come to other innovation activities like promoting new products and providing informational support for the introduction of new products. (Garcia & Mohnen, 2010).

Although developing countries seemed to be 'imitators' of technologies that always flow into their economies from developed countries through many different channels, developing countries are now becoming creators and holders of an increasing number of new technologies. The domestic R&D activities in developing countries is an important stimulus to their technology and economic development, especially when discussed at the firm level. Obviously, R&D is one of those activities that should not be left totally to the private firms. If so, it may soon result in under-investment. This is caused by the truth that private firms always fail to benefit from a full return of their R&D investment due to their difficulty in their own R&D efforts. (Arrow, 1962)

Thus, it is not hard to understand that the firms which receive the government innovation support related to R&D expenditures as with the R&D tax credits would be encouraged to commit more resources to R&D and international collaboration. We hypothesize that:

H5. Firms with greater government innovation support are more likely to have greater international openness in innovation.

III. Data and methods

We collected the data from China in this research because it presents a good case for the study of middle income countries. As China is considered as a fast rising innovation leader in the world, it is leading closer to international collaboration which expanding in every region of the globe. However, the research quality and innovative capability of China is still lower than the baseline of the world. In order to find a way to catch up with the developed countries, it is important to study the underlying mechanisms contributing to OI.

Our research uses the data from the 2008 Chinese national innovation survey. It contains data on manufacturing firms' international OI activities, and the research span extends from 2005 through 2007. The survey was carried out by the National Statistical Bureau. Tsinghua University helped us to design the questionnaire which shows high consistency with the design of the European Community Innovation Survey (CIS). This study covers 42 cities of China, not only inland regions but also coastal regions have been included. We receive a total number of 1,408 valid responses with a response rate of 83.6%.

All major different ownership types of firms that exist in China is 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 percent of the firms in the sample are of medium- and large-sized firms, respectively.

Table 1 demonstrates a breakdown of the originally selected firms according to their ownership characteristics. Table 2 shows the collaborative strategies for the different types of collaborators. About 48.2% of the selected firms consist of those claimed to have conducted collaborative innovation in 2005-07. The rate of collaboration (measured by the total amount of firms that have joined collaborative innovation as a percentage of all firms) varies from 32% of private firms, 11.6% of foreign firms and 4.6% of state-owned firms. Finally, it indicates that private firms are more likely to collaborate with other firms (32% 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%).

Table 1 Firm ownership and joined collaborative innovation

Firm ownership	Firms that have joined collaborative innovation			
	Yes		No	
	No. of firms	Proportion (%)	No. of firms	Proportion (%)
State-owned	64	4.6	58	4.2
Private	443	32.0	399	28.8
Foreign invested	161	11.6	260	18.8
Total	668	48.2	717	51.8

Table 2 Types of collaboration

Types of collaboration	With domestic partners	With international partners	Total number of collaborations	Do not collaborate
Other firms within affiliated group	315	119	434	223
Suppliers of equipment raw material or software	316	162	478	204
Users or consumers	291	187	478	217
Competitors or other firms within the same industry	222	106	328	318
Consultants or private R&D institutes	223	48	271	362
Universities or public R&D institutes	473	35	508	157

Measurement

International collaboration: In this study, the number equals 1 if a firm participates in any innovation activities with another firm and 0 otherwise as no collaborations. We distinguish between firms that cooperate with other firms which located in its own country, and firms that collaborate with other firms located in USA, EU, Japan, and other foreign countries all over the world. Then we count the number of international collaborations as well as the total number of collaborations. This allows for a direct examination of the issue as what significantly influences a firm's international openness in OI. Thus, the international openness in OI can be measured as:

$$\frac{number\ of\ international\ collaborations}{Total\ number\ of\ collaboration} \quad \text{(Breadth: 0 – 1)}$$

IOI is short for international open innovation, while ICO is short for international collaborations and CO is short for collaborations. The IOI index takes values from 0 (no international collaborations) to 1 (only international collaborations) as a proportion of openness to international collaborations. Formally this can be expressed as:

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

R&D intensity: R&D intensity is one of the major factors that strongly influence the firm's innovative performance. Firms that invest heavily in R&D activities have greater chance to achieve technology breakthrough (O'Brien, 2003).

Firm's domestic openness (previous experience): It is believed that having previous experience will increase the likelihood of two actors in different research institutions or enterprises to work together successfully. Uncertainty about how collaborators will behave in the future can be reduced by greater familiarity. Actors which have had previous

experience working together in the past will become familiar with each other's ideas, skills, and preferences, and as a consequence it will be easier for them to communicate with each other. Thus, they will feel more comfortable to work closely together (Cummings & Kiesler, 2008). We control and measure it through firms' rating regarding the prevalence of inter-firm and university-industry collaboration in the industry.

Strategic orientation: In this paper, we consider two types of strategic orientation. When the prospective innovation aims to strengthen a firm's technology leadership, we refer this as technology-oriented innovation. When a firm's objective to innovate is to expand market and strengthen its market leadership, we call it as market-oriented innovation.

Technology-oriented radical innovation: In this paper, we define technology-oriented radical innovation based on two indicators from the questionnaire. First, 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. Second, whether a firm has produced new to the world innovation in the past three years. Therefore, we proxy 'technology-oriented radical innovation' using 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 rest scenario.

Market-oriented radical innovation: We define technology-oriented radical innovation based on two indicators from the questionnaire. First, whether a firm has reported 'Prioritize entering new industry than grow its current market in R&D direction selection' as its main innovation strategy in the past three years. Second, whether a firm has produced new to the world innovation in the past three years. Therefore, we proxy 'market-oriented radical innovation' using 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 rest.

Similarly, we measure a firm's orientation to existing market expansion in innovation by a dummy variable which equals 1 if a firm has produced new to the world innovation and at the same time 'prioritize existing market expansion as its main innovation strategy' and 0 for the rest.

Admittedly, there are some limitations of this variable as a proxy of technology-oriented radical innovation. Firstly, radical innovation involves a fundamentally improvement over the old technology; leads to new products that are difficult to be replaced with substitute technology; and brings in substantial change in consumption preferences in the market (Zhou and Li, 2012). Therefore, whether a firm has new to the world novel innovation is not a perfect measure of radical innovation. The way the dummy variable is created makes assumptions that simplify the complexity of multi-orientation and multi-purpose situation.

Industry specific characteristics*:* Since technology dynamics may vary across sectors, we include a vector of industry dummy variables to proxy for it.

Endogenous uncertainty: There is no measurement of endogenous uncertainty that a firm face in innovation in the existing literature. In this paper, similar to the measurement of t*ask uncertainty* in the literature by product novelty, project complexity, and extent of design changes (eg., Pich et al., 2002; Takeishi, 2002; Lee & Veloso, 2008), we measure endogenous uncertainty in innovation by a weighted index of a firm's rating of the following four factors: (1) economic risks in innovation is too big; (2) the investment required by technology innovation is too much; (3) the firm lacks sufficient accumulated technology; and (4) the firm lacks relevant technological information for innovation. We assign an equal weight to each of these factors.

Firm exports *:* This is measured by the overall domestic export value.

Political support: We use government funding which received by firms as a measurement of political support. The government funding may include support that related to R&D expenditures as with the R&D tax credits. We believe firms which receive the government support would be encouraged to commit more resources to international collaboration. This study helps us to figure out whether the firms that receive public funding would have greater international openness in innovation than those that do not get any government support for OI.

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

- *Firm size:* It is measured by the total number of employees of a firm. Larger firms have a greater range of market opportunities through which to look for opportunities for international collaboration. The size of the firm can therefore act as a proxy for this enhanced incentive to cooperate. In particular, it may be much easier for larger firms to obtain resources for OI.
- *Firm age:* We believe that with the increasing of firm age, firms may have accumulated more experience and a larger knowledge base, thus they are more likely to have greater international openness in innovation. In contrast, older firms may be restricted by organizational rigidity and hence be less active in OI.

- ***Geographic location:*** The OI performance is mostly influenced by the way in which firms exchange resources with their surrounding environment. The environment may either be seen as a network of actors (other organizations) nearby with which the firm collaborate or as a general background for firm action: social values, human resources and political cultures, etc. (Smith et al., 1995). We use a vector of regional dummies to represent the impact of innovation environment.

IV. Results

We first used a widely accepted methodology which is Heckman's (1976, 1979) two-step model to explore the data. We choose this model because it offers a means of correcting for non-randomly selected samples and allows us to correct for selection bias. An initial binary model estimates the probability of a firm undertaking collaboration in the first equation, and a second stage OLS containing a selection correction term derived from the first equation to capture the determinants of IOI. The IOI index takes values from 0 (no international collaborations) to 1 (only international collaborations) as a proportion of openness to international collaborations.

As we want to examine what makes Chinese firms more active to collaborate with foreign firms, variables indicating factors which will shape firms' cooperative activities have been included in the model. As shown in Table 3 which illustrates the result of different models, we include a firm's R&D expenditure and previous experience in Model 5. We include the sector dynamics in Model 4. The uncertainty of a firm is included in Model 3. The international-orientation, market-orientation and technology-orientation are included in Model 2. A dummy variable to represent a firm receiving financial support from the government for open innovation is included as an explanatory variable in Model 1, as this may enable a firm's financial capacity for collaborative activities. Variables representing firm-specific characteristics such as ownership type, firm size, firm age and firm location are included in all these models.

Table 3: International openness in innovation: The Heckman model

	International openness in innovation					
	M1	M2	M3	M4	M5	M6
Previous experience	0.007 (0.023)	0.001 (0.024)	-0.000 (0.024)	-0.015 (0.022)	-0.015 (0.022)	
R&D Investments (log)	-0.004* (0.002)	-0.005** (0.002)	-0.005** (0.002)	-0.005** (0.002)	-0.006*** (0.002)	
Dummy High-tech firm	0.055** (0.026)	0.050* (0.027)	0.049* (0.027)	0.043 (0.027)		
Endogenous uncertainty	-0.007 (0.004)	-0.006 (0.004)	-0.006 (0.004)			
Structural uncertainty	-0.004 (0.005)	-0.005 (0.005)	-0.003 (0.005)			
Technology-oriented radical innovation	0.018 (0.031)	0.008 (0.031)				
Market-oriented radical innovation 2	0.099* (0.046)	0.099** (0.047)				
Firm exports	0.109*** (0.025)	0.099*** (0.025)				
Dummy received governmental funds	-0.076*** (0.019)					
Total number of collaborations	0.029*** (0.003)	0.028*** (0.003)	0.030*** (0.003)	0.029*** (0.003)	0.029*** (0.003)	0.029*** (0.003)
Dummy < 300 employees	-0.070** (0.032)	-0.68*** (0.032)	-0.097*** (0.032)	-0.097*** (0.031)	-0.100*** (0.031)	-0.116*** (0.036)

Dummy < 300-2000 employees	-0.040	-0.038	-0.051**	-0.051**	-0.055**	-0.055**
	(0.025)	(0.025)	(0.025)	(0.025)	(0.026)	(0.026)
Age of the firm	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Firms located in the coastal area	0.062***	0.066***	0.083***	0.080***	0.082***	0.081***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Foreign firm	0.118***	0.135***	0.153***	0.163***	0.169***	0.156***
	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.033)
_cons	0.166	0.162*	0.216*	0.123***	0.142***	0.072*
	(0.119)	(0.120)	(0.127)	(0.039)	(0.041)	(0.039)
	Worked with other organizations in the past three years or not					
Dummy < 300 employees	-0.367***	-0.367***	-0.361***	-0.376***	-0.372***	-0.395***
	(0.123)	(0.123)	(0.123)	(0.122)	(0.122)	(0.124)
Dummy < 300-2000 employees	-0.055	-0.055	-0.051	-0.052	-0.049	-0.065
	(0.108)	(0.108)	(0.109)	(0.108)	(0.108)	(0.108)
Age of the firm	0.003	0.003	0.003	0.002	0.002	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Firms located in the coastal area	-0.077	-0.077	-0.079	-0.072	-0.073	-0.063
	(0.086)	(0.086)	(0.086)	(0.085)	(0.085)	(0.086)
Foreign firm	-0.415***	-0.415***	-0.418***	-0.406***	-0.408***	-0.390***
	(0.093)	(0.093)	(0.093)	(0.092)	(0.092)	(0.093)
Firm exports	0.145	0.145	0.163*	0.153	0.160*	0.098
	(0.089)	(0.089)	(0.096)	(0.097)	(0.095)	(0.099)
Knowledge base	0.265***	0.264***	0.263***	0.238***	0.236***	0.240***
	(0.081)	(0.081)	(0.081)	(0.080)	(0.080)	(0.080)
Dummy High-tech firm	0.205*	0.206**	0.207**	0.198*	0.208**	0.176*
	(0.105)	(0.105)	(0.105)	(0.104)	(0.106)	(0.106)
R&D Investments (log)	0.088***	0.088***	0.088***	0.086***	0.085***	0.087***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
_cons	-0.049	-0.050	-0.062	-0.024	-0.032	0.106
	(0.144)	(0.144)	(0.146)	(0.145)	(0.145)	(0.147)
Athrho	0.002	-0.014	-0.090	-0.072	-0.110	-0.190
	(0.061)	(0.055)	(0.064)	(0.068)	(0.067)	(0.148)
Lnsigma	-1.355***	-1.346***	-1.325***	-1.317***	-1.313***	-1.303***
	(0.038)	(0.038)	(0.038)	(0.037)	(0.037)	(0.042)

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

The role of strong technology capabilities and technology-oriented radical innovation: Leading to In-house innovation

Table 3 reports the estimated results for determinants of International openness in innovation using the Heckman model corrected for potential selection bias. To test Hypotheses 1, we first regressed firm's R&D intensity and previous experience to all control variables. Column (5) shows the role of technology capabilities in international collaborative activities. From Model 5, we find the R&D intensity has a significantly negative relationship with firm's international openness in innovation ($\beta = -0.004$, $p < 0.01$), which is opposite to the hypothesis 1a we supposed before. Also, we find that the previous experience appears to be a positive but insignificant factor in firm's choice to collaborate with foreign partners, which provides no evidence for hypothesis 1b.

As the Chesbrough's 'open innovation' model (Chesbrough, 2003a, 2003b) suggests, any innovative firms which spend too much on R&D activities are not able to draw on knowledge and expertise from a wide range of external sources. Chesbrough (2003b) also suggests that firms that are 'too focused internally' are 'prone to miss a number of opportunities.' This is likely due to the firms' own technology capabilities that enable them to create a vision, a target which if achieved will create outstanding products and provide them with an irreplaceable market position. (Lawson & Samson, 2001) Thus, they do not need to try to succeed by searching for collaborators or matching others. Instead, they themselves seek to be "the best of the best".

Then we entered technology-oriented radical innovation in model 2. Although many firms in the high-technology industry are born with an international orientation (Filatotchev et al., 2009), from column (2), we found that the estimated coefficient of the technology orientation exhibits a positive but insignificant effect on international openness in innovation, which provides no evidence for hypothesis 3a.

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, even if these new products cost more resources". Therefore, we believe that firms with both strong technology capabilities and technology orientation would prefer to develop in-house innovation. Because when they are willing to develop something new to the world, they can't wait for such a long time to find a suitable foreign partner. All they need is to keep up speed which enables firms to grab more opportunities and win the competition in the market.

Firm age also appears to have a significant effect on firm's willingness to cooperate with foreign firms. As it indicates, the younger the firm is, the more the likelihood the firm will conduct International collaborative activities.

The role of market-oriented radical innovation: leading to cooperation

Column (2) also reports the results of regressions after entering the market-oriented radical innovation into Model 2. There is a direct positive relationship between market-oriented radical innovation and international openness in innovation ($\beta = 0.099$, $p < 0.05$), which supporting hypothesis 3b.

The reason why market-oriented innovation acted as a more crucial factor than technology-oriented innovation can be summarized as follows. First, firms need to gain knowledge from their foreign partners about the target buyers in the certain market. With the help of international collaboration, they are able to identify, to analyze, to understand, and to answer user needs, so that they could create superior value for them continuously. Second, these two strategic orientations may occur in different stages of innovation. As Lee et al. (2010) suggested that open innovation activities are more effective at later innovation stages when the firm already has something to provide to prove themselves in the market. During the early stage of innovation, firms have to search depth to find the

suitable and trustworthy partners to do the R&D activities together, which is a very time-consuming process. However, as 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 comes so close to international openness in innovation than technology orientation.

The role of great sector dynamics: leading to cooperation

The estimated results of the role of sector dynamics using the Heckman model are reported in Model 4. The International openness in innovation is used as dependent variable in this regression. From column (4), we find that a high-tech firm has a positive impact and are significantly related to international openness in innovation ($\beta = 0.049$, $p < 0.1$). Although the estimated coefficient is only marginally significant at the 10% level, the results still appear to support the hypothesis 2a.

These dynamic industries include consumer electronics (Christensen et al., 2005), automotive (Ili et al., 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 high technology difficulties. Most firms in these industries are interested in cooperating with foreign firms in this time-consuming process, for the purpose to reduce costs and uncertainties, as well as expanding international market. Also, unlike nuclear or military industries, most products in these industries are designed only to make profits. Firms across countries can cooperate in their area without too much political concern. Thus, we can easily draw the conclusion that international openness in innovation seems to be a matter of high-tech industries.

The role of great uncertainty: leading to In-house innovation

From model 3, we find that the estimated results exhibit some interesting but unexpected findings. The results in column (3) suggest that endogenous uncertainty of a firm have a negative but insignificant impact on international openness in innovation, which does not provide strong evidence for hypothesis 2b. However, the effect of endogenous uncertainty on IOI is still negative using OLS and Tobit model, but it changes from statistically insignificant to marginally significant. Those results are showed in Table 4 and Table 5.

As discussed earlier, the results are likely due to the firm's inability to grasp the key information for a successful project. The high level of endogenous uncertainty means a firm is uncertain about how much time, effort, and resources will be needed to accomplish the specific R&D activities, which leads to the likelihood of technical failure. To reduce the endogenous uncertainty, firms may choose to minimize risk by investing in technology with great promise, instead of looking outside for foreign partners to conduct radical innovation.

The role of International orientation： Leading to cooperation

We conducted logistic regression and entered the firm exports as a dummy variable into the Model 2. From column (2), we observe that firm's exports appear to be significantly associated with international openness in innovation ($\beta = 0.109$, $p < 0.01$). The results indicate that hypothesis 4 has been 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, 1993) found that international trade allows a bidirectional information exchange of across countries. Competing in the overseas market facilitates exporting firms to learn from foreign agents or directly from customers (Salomon, R. M., & Shaver, J. M. 2005). The knowledge exchange from the foreign market helps firms to learn by exporting. Thus it becomes easier for firms with a high degree of globalization to communicate with foreign partners, as they have previous experience of participating in international trade before. The smooth communication and better mutual understanding help both sides to build trust between each other. Thus, they are more likely to make decisions in conducting innovation activities and developing new products together.

The role of government funds ：Leading to In-house innovation

To test Hypothesis 5, we entered the governmental funds, which received by a firm, into Model 1. We found a negative correlation between government support and international openness in innovation, which is opposite to the hypothesis 5 we supposed before ($\beta = -0.076$, $p < 0.01$).

As Mani, S. (2004) argued, the ultimate goal of the innovation policy of a state was to promote local development of science and technology. Thus, government funds and various policies have been put into effect by the country to encourage SMEs to conduct R&D projects within their enterprises. Even if they need to collaborate, firms which receive financial support from government are more likely to work with domestic research institutions.

This also can probably be explained by some factors which may hinder firms from conducting innovation collaboration. Although the firms which receive government funds have the willingness to collaborate with other firms overseas, the successful partnership may be influenced by the culture distance between organizations. The absorptive capacity, firm size and firm age also be confirmed to have significant impacts on firms' possibility to collaborate with firms in other countries.

Table 4 Robustness test: Determinants of international OI estimated by OLS model

	International openness in innovation OLS	
	Coef.	Std.err.
Previous experience	0.029***	0.003
Dummy High-tech firm	0.058**	0.026
Endogenous uncertainty	-0.007*	0.004
Structural uncertainty	-0.004	0.005
Technology-oriented radical innovation	0.017	0.032
Market-oriented radical innovation	0.099**	0.041
Worked with other organizations in the past three years or not	-0.375	0.266
Firm exports	0.110***	0.026
Dummy received governmental funds	-0.073***	0.026
Dummy < 300 employees	-0.069**	0.034
Dummy < 300-2000 employees	-0.038	0.026
Age of the firm	-0.001**	0.001
Lack of human capital for innovation	0.010	0.024
Firms located in the coastal area	0.060***	0.023
Foreign firm	0.121***	0.026
R&D Investments (log)	-0.004**	0.002
_cons	0.547*	0.288

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

Table 5 Robustness test: International openness in innovation estimated by tobit model

	International openness in innovation tobit	
	Coef.	Std.err.
Previous experience	0.064***	0.007
Dummy High-tech firm	0.087	0.057
Endogenous uncertainty	-0.017*	0.009
Structural uncertainty	-0.008	0.010
Technology-oriented radical innovation	0.025	0.070
Market-oriented radical innovation	0.175**	0.087
Worked with other organizations in the past three years or not	-0.695	0.520
Firm exports	0.306***	0.063
Dummy received government funds	-0.119**	0.051
Dummy < 300 employees	-0.130*	0.076
Dummy < 300-2000 employees	-0.089	0.058
Age of the firm	-0.004***	0.001
Lack of human capital for innovation	0.026	0.054
Firms located in the coastal area	0.163***	0.054
Foreign firm	0.209***	0.055
R&D Investments (log)	-0.006	0.004
_cons	0.475	0.576

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

Table 4 reports the results of a robustness test using an OLS model. The estimated results are broadly consistent with the Heckman model estimates, especially the effect of government funds, firm exports and sector dynamics which remain at the same significant level as before. The estimated coefficient of R&D investments and firms' market-oriented radical innovation are more statistically significant than Heckman model, which lead to the same conclusion. Moreover, the previous experience and endogenous uncertainty become statistically significant, which are better results than before. These facts suggest that most of our original hypotheses have been supported.

The estimated results of a robustness test using a Tobit model are reported in Table 5. The previous experience and endogenous uncertainty have become a significant contributor to the choice of cooperation; The R&D investments is not statistically significant although the negative result is the same as the Heckman model. Firm exports again contribute significantly to the international open innovation. The market-oriented radical innovation and government funds are also statistically significant.

To sum up, the robustness check identifies the results mostly robust.

V. Conclusions and discussions

Our study examines the five key factors which influence the likelihood of firms to undertake international open innovation. The study is based on the Chinese national innovation survey database which covers manufacturing firms in 42 cities. It builds on and supplements previous literature in the following three ways.

First, this study provides us with an opportunity to understand the determinants of international OI. While consequences of acquiring external resources for an organization's innovation process have been well researched, we still have little insight into what happens inside a firm helping or hurting a it's ability to put itself into the OI process. (Tucci, Chesbrough, Piller, & West 2016). Moreover, the external environment such as political support that motivated the organizations to initiate their OI activities is often not well understood. All in all, following the original and more recent conceptualizations (Chesbrough, 2003, 2006a; Gassmann & Enkel, 2004; Dahlander & Gann, 2010; West & Bogers, 2014; Chesbrough & Bogers, 2014) which define OI as a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, this study helps us to know how a wide set of incentives and motivations contribute to a firm's OI process.

Several factors have been found to be the key determinants of international openness in innovation. Both firm exports and market orientation are important for building international collaboration effectively. Considering the collaboration between the Chinese firms and firms abroad, firms have to learn to deal with the substantial differences in market demand and technical conditions between the partner countries, the significant organizational culture distance between the partners, and the difficulties of trust-building between partners. Our study helps to know the role of organizational learning in the decision-making process which strongly related to the organizational open innovation. It seems as a critical mechanism by which organizations develop capabilities and get used to their dynamic and uncertain environment. When viewed from a behavior change or implementation perspective, organizational learning is equivalent to the capacity to innovate. Thus, our study considers the timing of different actions and the context of each act, especially in the dynamic industries.

Then we found some determinants of IOI which are opposite to our original hypotheses and lead to in-house innovation. From the resourced-based view, most studies focus on resources mainly within the firm, or within the value chain in which the firm is embedded. This article extends the resource-based view with the external environment and to explore the surrounding networks represent useful resources which could help firms to create value (Chesbrough, & Appleyard, 2007). As most of the traditional views do not pay much attention to the potential value of external resources that are not owned by the firm, but may create value for the firm unexpectedly. Although the results do not support the

hypothesis that technology capability and technology orientation can work as the trigger of international partnerships which can enhance value creation (Enkel, 2010), it provides us a point of view that firms spend too much on internal R&D activities may not be able to gain knowledge and experience from various external sources. Moreover, government funds do not appear to be as effective as we expected to encourage international collaboration, which has important policy and implications.

We have several recommendations to advance research in this area. First, more work must be done to untangle the constructs of international OI, and to understand the factors which increase the likelihood of firms to undertake IOI. As part of the OI process, the underlying mechanisms which promote OI should be examined in more depth. Second, it should be incorporated into future models of how organizations develop their innovation capabilities over time, how they adapt to the dynamic external environments, and how this affect their decision of undertaking international OI. This would enhance our understanding of how firms learn, change, and perform over time. Future research should examine this issue by collecting data from a longer time period.

Finally, care should be taken when generalizing these results to other populations because all the respondents were from the Chinese manufacturing firms. While the present study examined the determinants for firms to undertake international OI, it did not investigate how universities and other research institutions react under the same situation. Also, although the time period we choose in this paper is an important and fast-developing period of China that is worthy of study, more work must be done to understand the whole process of international OI in the new area. Moreover, many manufacturing firms in developing countries are under tremendous pressure to change. More research is needed to determine how these organizations can become more open to innovation.

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