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Business School, The University of Western Australia; School of International Trade and Economics, University of International Business and Economics, Business School, The University of Western Australia, School of International Trade and Economics, Central University of Finance and Economics

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Does Innovation Matter for Chinese High-tech Exports? A Firm-level Analysis*

Dahai Fu[a,b], Yanrui Wu[a] and Yihong Tang[c]

[a] Economics, Business School, The University of Western Australia, Perth, Australia; [b] School of International Trade and Economics, University of International Business and Economics, Beijing, China; [c] School of International Trade and Economics, Central University of Finance and Economics, Beijing, China

Abstract

This paper examines the effect of innovation on export decision in Chinese high-tech firms during the period of 2005-2007. Using a parametric, instrumental variable approach and a non-parametric matching method, we find that firm-level innovation efforts, measured by R&D spending and new product output, play only a minor role for domestic exporters. Foreign-invested firms dominate the high-tech exports but do not rely on indigenous innovation activities. These results thus confirm prior findings that the success of Chinese high-tech exports does not result from heavy R&D expenditure and technological progress. Moreover, different types of innovation measures show different impacts on the likelihood of exporting. The impacts of innovation on exporting vary widely across industries and Chinese regions.

Key words: Exporting, Innovation, High technology, China

JEL classifications: F14; O32; O53

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1. Introduction

Over the past two decades, the global map of exports has changed dramatically due to the arrival on the market of high-technology products from developing countries. The striking transformation in the export pattern has led economists to question whether the success of high-tech exports from developing countries is real or just a 'statistical illusion' (Srholec 2007). Although some optimists consider it a positive signal that emerging economies are climbing up the ladder in the global value chain and competing head-to-head with developed countries in high-tech[1], some skeptics have pointed out that the expansion of the high-tech exports from developing countries is largely due to their active engagement in the labor-intensive processing stages within high-tech industries resulting from the international fragmentation of production (Lall, 2000; Mayer et al., 2002; Srholec, 2007; Athukorala, 2009).

This paper contributes to this debate by examining whether firm-level innovation enhances the likelihood of exporting in the context of the Chinese high-tech sector during the period of 2005-2007. Several authors have analyzed the impact of innovation on export participation at the firm level. Examples include Caldera (2010) on Spain, Damijan et al. (2010) on Slovenia and Van Beveren and Vandenbussche (2010) on Belgium. China's case is especially interesting for the following two reasons. First, its high-tech exports have been growing at an average annual rate of 36.1% during the post-WTO period (2002-2009) and account for over 30% of China's total exports in recent years. As a result, in 2006, China overtook the U.S. and the E.U. to become the largest exporter of high-tech products worldwide (World Bank,

[1] In a recent report (*The Economist, April 17th, 2010, p.9*), it is stated that: "...Emerging countries are no longer content to be sources of cheap hands and low-cost brains. Instead, they too are becoming hotbeds of innovation, producing breakthroughs in everything from telecoms to carmaking to health care. …Developing countries are competing on creativity as well as cost."

2008). Second, China's government has adopted encouraging policies in high-tech industry since the 1990s with the aim of promoting technological progress and accelerating the development of high-tech industry. However, the dominance of foreign-invested enterprises with lower R&D expenditure in the high-tech exports has cast doubt on the government's policy on high-tech industries. Whether domestic firms can become major players through indigenous innovation will matter for the sustainable growth of Chinese high-tech exports in the next few decades. Thus, this paper has important policy implications.

In this paper, we test the relation between innovation activities and the likelihood of exporting in the context of the Chinese high-tech sector. [2] The differences between foreign-invested enterprises and domestic firms are considered carefully. The endogeneity of innovation is examined using an instrumental variable (IV) approach and a non-parametric matching technique to double-check the impact of innovation on export participation. In addition, we analyze this relation in key industries and provinces. Our main findings can be summarized as follows. First, innovation activities play a minor role in determining export propensity for Chinese high-tech firms. Second, innovation efforts, measured by R&D spending and new product output, are not a factor contributing to the export propensity of foreign-invested enterprises, whereas they have a positive but small impact on the likelihood of exporting for indigenous firms. Third, the effects of different types of innovation on firm export participation differ, although it is unclear which is more important. Fourth, the effects of innovation on export propensity vary significantly across industries and provinces.

The rest of the paper is organized as follows. We present an overview of innovation and export performance in the Chinese high-tech sector in Section 2 and review the relevant literature in Section 3. The empirical model and data are discussed in Section 4. The baseline

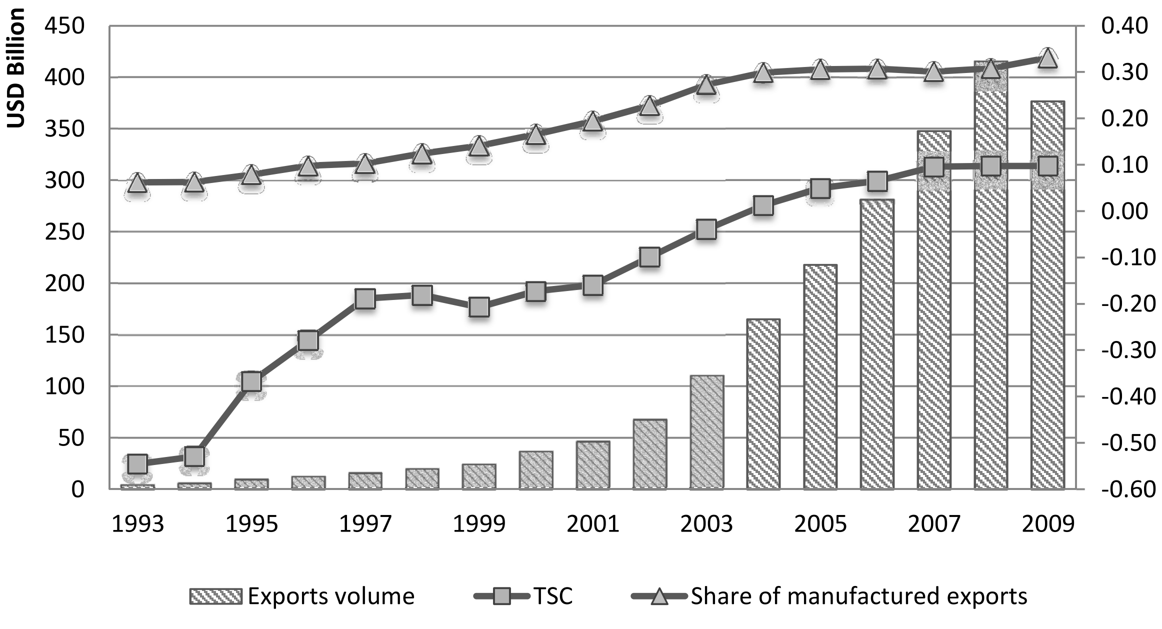
[2] Huang et al. (2008) analyze the relation between innovation and export intensity using a similar dataset during the period 2001-2003 but their estimation strategy is completely different from ours.

regression results and discussion are presented in Section 5, with Section 6 presenting some further analyses. Section 7 concludes the paper.

2. Overview of Exports and Innovation in the Chinese High-tech Sector

According to the National Bureau of Statistics of China (NBSC), the high-tech sector is broadly classified into five sub-industries: (1) pharmaceuticals; (2) aircraft and spacecraft; (3) electronic and telecommunication equipment; (4) computers and office equipment; and (5) medical equipment and meters (for details, see *Appendix-Table 1*). This definition is compatible with OECD's classification of high-technology industries.

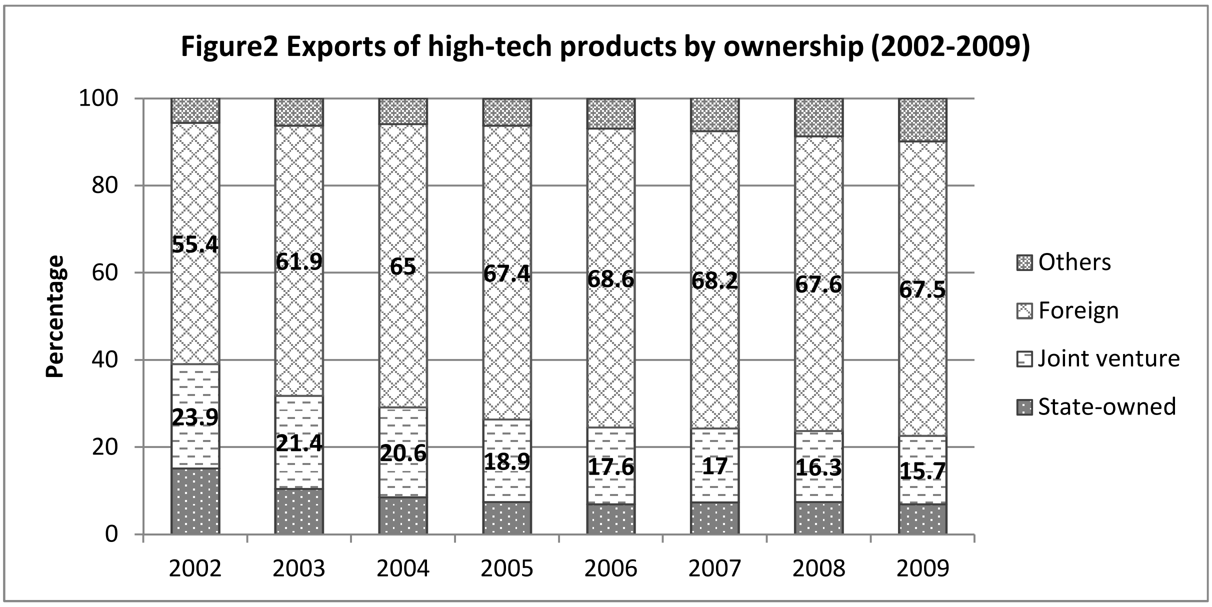
Figure 1 China's High-tech Exports Performance (1993-2009)



Source: China Science and Technology Statistics (2010).

Figure 1 shows that China's high-tech exports enjoyed an average increase of 34.4% annually between 1993 and 2008, which was not seen in 2009 due to the financial crisis. Correspondingly, the share of high-tech exports in China's total manufacturing exports rose from 6.2% in 1993 to over 30% in recent years, which is even higher than the shares in most developed countries. Moreover, China's competitiveness in the international market has improved since 2004. This change can be partly reflected by the trade specialization coefficients (TSC, measured by the ratio of trade balance to total trade) in high-tech sector, which rose from -0.55 in 1993 to 0.10 in 2009. It indicates that China has been a net exporter of high-tech products since 2004. According to the World Development Indicators 2009 (World Bank, 2009), China, as the largest exporter of high-tech products, accounted for 18.6% of the world market in 2007, followed by the U.S. (12.7%), Germany (8.6%), and Japan (6.7%) .

However, foreign-invested enterprises still account for most of China's high-tech exports in recent years. Figure 2 illustrates the composition of high-tech exports by ownership between 2002 and 2009. Foreign firms (including enterprises originated from Hong Kong, Macau and Taiwan) accounted for more than 55% of total high-tech exports in 2002, and this number reached 67.5% in 2009. During the same period, the share of state-owned enterprises decreased from 15.1% to 6.9%. The share of others was smaller but increasing, which may indicate that privately and collectively owned enterprises are increasingly involved in high-tech exports. According to these statistics, it is necessary to consider ownership in the following analysis.



In addition to exports, we present an overview of innovation efforts in the Chinese high-tech sector. China's innovation efforts have been driven by the desire to establish an innovative society. In 2008, China invested 1.52 % of its GDP in R&D, whereas this figure was 0.64 % in 1994 (NBSC, 2009). The country's *National Medium-to-Long Term Plan for the Development of Science and Technology (2006-2020)* states that the government aims to increase the share of GDP invested in R&D to 2% by 2010 and to over 2.5 % by 2020.

Table 1 shows that the R&D intensity of high-tech industries, defined as the percentage of R&D expenditure over the value-added, increased from 5.1% in 2001 to 6.0% in 2007. Among the five sub-industries, aircraft and spacecraft had the highest R&D intensity, followed by electronic and telecommunication equipment. Nevertheless, it should be noted that R&D intensity in China is still very low compared with developed countries. For instance, the R&D intensities of high-tech industries reached 39.8% and 28.9% for the US and Japan, respectively, in 2006 (OECD, 2009).

Table 1 China's R&D intensity of high-tech industries (2001-2007)

Sector	2001	2002	2003	2004	2005	2006	2007
Manufacturing	2.6	3.4	2.0	1.9	3.2	3.4	3.5
High-tech Industries:	5.1	5.0	4.4	4.6	5.6	5.7	6.0
(1) Pharmaceuticals	2.7	2.6	2.7	2.4	4.0	4.7	4.7
(2) Aircraft and spacecraft	13.3	15.0	15.8	16.9	13.9	14.9	15.4
(3) Electronic and telecommunication equipment	6.5	5.8	5.4	5.6	6.9	6.4	6.8
(4) Computers and office equipment	2.5	4.1	2.5	3.2	2.7	3.8	3.9
(5) Medical equipment and meters	2.7	2.5	3.0	2.5	6.3	5.2	6.3

Source: China Statistics Yearbook on High Technology Industry 2002-2008.

According to Table 2, both R&D inputs and outputs in Chinese high-tech industries increased between 1995 and 2008. The numbers of R&D personnel rose considerably, from 57,838 to 285,079, and the share of national employment increased from 1.3% in 1995 to

3.0% in 2008. R&D expenditure increased dramatically, from US$0.21 billion in 1995 to US$9.43 billion in 2008. Moreover, the expenditure on new products grew from US$0.39 billion to US$11.49 billion. [3] The last two columns in Table 2 show the output of innovation in terms of revenue from new products and the number of patent applications. In 1995, the revenue of new products was US$6.45 billion, which accounted for 13.7% of total sales of high-tech products. The figure increased to US$185.45 billion in 2007, while the share in total sales fluctuated around 23.1 %.

Table 2 Science and technology indicators of China's high-tech industries (1995-2008)

Year	R&D Personnel (Person-Year)	R&D Expenditure (Billion US$)	Expenditure For New Products (Billion US$)	Revenue from New Products (Billion US$)	Patent Applications (Number)
1995	57,838 [1.3][a]	0.21	0.39	6.45 [13.7][b]	612
1996	90,594 [2.0]	0.37	0.50	8.40 [15.5]	545
1997	96,089 [2.2]	0.51	0.63	9.71 [14.3]	713
1998	70,879 [1.8]	0.68	0.86	14.58 [18.3]	1,076
1999	92,589 [2.4]	0.82	1.14	18.43 [19.5]	1,482
2000	91,573 [2.3]	1.34	1.42	30.00 [24.8]	2,245
2001	111,572 [2.8]	1.90	1.62	34.75 [23.9]	3,379
2002	118,448 [2.8]	2.26	2.04	41.27 [23.4]	5,590
2003	127,849 [2.7]	2.69	2.51	54.55 [22.1]	8,270
2004	120,830 [2.1]	3.53	3.13	73.69 [21.9]	11,026
2005	173,161 [2.6]	4.43	5.07	84.41 [20.4]	16,823
2006	188,987 [2.5]	5.73	6.40	103.48 [19.8]	24,301
2007	248,228 [2.9]	7.17	8.57	135.50 [21.5]	34,446
2008	285,079 [3.0]	9.43	11.49	185.45 [23.1]	39,656

Note: The values in Columns 3-5 were calculated according to the exchange rate of Renminbi to the US dollar (Period Average) reported in China Statistics Yearbook 2008.
[a] The numbers in the brackets represent the percentage of R&D personnel in total employment of high-tech industries. [b] The numbers in the brackets represent the percentage of the revenue from new products in total sales revenues of high-tech products.
Source: China's High-tech Industries Data.

[3] According to the NBSC, new products are the "products that involve the use of new principles, incorporate design improvements, utilize new materials, or embody new techniques; and existing products that are used for new functions or expand capabilities also constitute new products." (Jefferson et al., 2003, p.107).

In relation to patent applications, whereas there were only 612 cases in 1995, the aggregate data show an increasing trend in numbers of patent applications up to 2008. The number of patent applications reached 39,656 in 2008.

3. The Existing Literature

Technological progress and structural changes in trade patterns have usually been regarded as two important indicators of the economic development of a country. However, the good performance in high-tech exports of developing countries has been questioned by some economists. Lall (2000) provided a comprehensive mapping of the technological structure and performance of manufactured exports from developing countries between 1985 and 1998 and noted that many developing countries became exporters of high-tech products. However, the author concluded that the outstanding performance in high-tech exports observed in developing countries might be 'something of a statistical illusion' resulting from their specialization in the labor-intensive processes within high-tech-intensive industries.

Similar findings were reported by Mayer *et al*. (2002), who found that many developing countries did not gain technological progress from their rapid growth of high-tech exports. Mani (2000) and Srholec (2007) investigated whether the growth of high-tech exports from developing countries was due to technology spurts or international production sharing. Mani (2000) examined the performance of the newly industrialized Asian economies (i.e., Singapore, Malaysia, the Philippines, Thailand, and Korea) between 1988 and 1998. The author found that the majority of high-tech exports from these developing countries were conducted by multinational enterprises with very little local R&D effort in terms of patent activities. However, it was found that Korean and Taiwan were enjoying increasing technological capabilities. Srholec (2007) reported that the bulk of high-tech exports resulted from international fragmentation of electronics production. These findings thus indicate that we cannot directly relate the outstanding performance in high-tech exports of some developing countries to their technological progress from the perspective of international fragmentation of production.

Nevertheless, a major shortcoming of the aforementioned studies is the aggregate nature of their analyses, which limits our understanding of the role of firms that actually make the decisions regarding innovation activities and high-tech exports. A large and growing number of recent studies have sought to deal with the link between firms' export participation and their innovation activities (Aw et al., 2007; Aw et al., 2009). However, the results are mixed. Many authors have reported a positive and significant impact of innovation efforts on export propensity and export performance. For example, Harris and Li (2009) studied the relation between R&D and exports for UK manufacturing firms and found that R&D plays a critical role for new exporters. Similar results are reported by Lee and Stone (1994) for U.S. manufacturing firms. For China, Zhao and Li (1997), using a sample of 1,743 leading manufacturing firms from 1992, found that R&D had a significant and positive influence on export propensity and growth. In addition, we also see some contradictory findings in the literature. For instance, Wakelin (1998) found that UK innovators are less likely to become exporters compared to non-innovators of the same size. Aw et al. (2007) and Cassiman and Martinez-Ros (2007) failed to find a significant link between firm-level R&D and export propensity using data on manufacturing firms in Taiwan (China) and Spain, respectively. In the case of China, Huang et al. (2008) also showed that R&D has not been a contributing factor to the export success of Chinese firms, even in high-tech sectors, and they suggest processing trade as an explanation for the success of Chinese high-tech firms in global markets.

As pointed out by Van Beveren and Vandenbussche (2010), the mixed effects of innovation on firms' export propensity seem to depend on the measures of innovation. Several authors use alternative measures of firm-level innovation besides the indicator of R&D. Nguyen et al. (2008) used three measures of innovation, namely product innovation, process innovation and modification of existing products. They found that all three measures of innovation are statistically significant determinants of exporting for Vietnamese small and medium enterprises. Recently, Van Beveren and Vandenbussche (2010), Damijan et al. (2010) and Caldera (2010) have all measured innovation by innovative effort (R&D) as well as by innovative output (product and process innovation). While Caldera found a positive effect of innovation on the probability of export participation for Spanish manufacturing firms, Van Beveren and Vandenbussche and Damijan et al. concluded that neither product nor process innovation increases the likelihood of firms' export participation in the context of Belgium and Slovenia, respectively.

With respect to the econometric methods, the probit model is always preferred. Several estimation methods are subsequently employed to deal with three different types of endogeneity issues between innovation and exporting (Van Beveren and Vandenbussche, 2010). To account for the simultaneity problem, most authors have used lagged innovation and other firm-level characteristics as potential determinants of firms' propensity to export to avoid a feedback effect. To control for the causality bias due to the persistence of firm-level exports, many authors have estimated a dynamic model by adding a lagged dependent variable, namely lagged export status, on the right-hand side (e.g., Caldera, 2010) or have limited the sample to new exporters only (e.g., Van Beveren and Vandenbussche, 2010). Finally, to handle the endogeneity of innovation in export decisions due to the anticipation effect (Costantini and Melitz, 2007)[4], authors have often employed the instrumental variable approach (e.g., Lachenmaier and Woßmann, 2006; Nguyen et al., 2008) or estimated a bivariate probit model (e.g., Aw *et al.,* 2007; Girma *et al.,* 2008). More recently, Becker and Egger (2007) and Damijan et al. (2010) used the propensity score matching approach to establish the direction of causality between innovation activity and exporting.

4. Empirical Model and Data

4.1. Empirical model

Following previous studies, such as Roberts and Tybout (1997) and Bernard and Jensen (1999), we assume that the decision to export is made by rational and profit-maximizing firms. A firm i decides to export in period t if its expected gross profit is greater than that from sales in the domestic market only. Caldera (2010) develops a simple theoretical model of the firm's decision to export and innovate. The model predicts that more innovative firms will be more likely to export because innovative firms have lower marginal costs of production, which makes them more profitable compared to non-innovative firms in the foreign market.

To examine the effect of innovation activities on the export decision of a firm, we incorporate the innovation variables into the framework developed by Roberts and Tybout (1997). The specification can be presented as follows:

[4] Costantini and Melitz (2007) found that the anticipation of upcoming trade liberalization can induce firms to innovate prior to their entry into the export market, which leads to the endogeneity of innovation when empirically analyzing the link between firm-level innovation and exporting activities.

$$EXP_{it} = \begin{cases} 1 & if \;\; EXP_{it}^{*} > 0 \\ 0 & otherwise \end{cases} \tag{1}$$

$$\mathrm{EXP}_{\mathrm{it}}^{*} = \lambda + \alpha \mathrm{EXP}_{\mathrm{i,t\text{-}1}} + \beta \mathrm{INN}_{\mathrm{i,t\text{-}1}} + \gamma_{\mathrm{x}} \mathrm{Z}_{\mathrm{i,t\text{-}1}} + \varepsilon_{\mathrm{it}}$$

Where

- EXP_{it} is the export dummy of firm *i,* which equals 1 if a firm exports and zero otherwise.
- $EXP_{i,\, t-1}$ is a lagged dependent variable to control for the presence of sunk entry cost.
- $INN_{i,\, t-1}$ is a dummy variable and has a value of 1 if the firm is involved in innovation activities in that year and zero otherwise. Here we use two different measures of innovation activities that capture both the innovation input, such as R&D expenditure, and the innovation output, such as product innovation.
- $Z_{i,\, t-1}$ denotes a vector of other firm characteristics associated with the firm's decision to export, which include total factor productivity (TFP) to control for firm efficiency[5], a foreign-invested enterprises (including those from Hong Kong, Macau and Taiwan) dummy (FIE, for details, see *Appendix-Table 3*), industry concentration as measured by the Herfindahl-Hirschman Industrial Concentration Index (HHI) at the 3-digit industry level to capture industry-level competition, and the coastal region dummy[6] which equals 1 if the firm locates in the coastal region, to capture the effect of firms' location on their export propensities.

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[5] Total factor productivity (TFP) is estimated using the semiparametric approach by Levinshon and Petrin (2003). We use the *Stata* command *levpet*, which estimates the production function using intermediate inputs to control for unobserved productivity shock. We estimated value-added-based production functions separately for the five high-tech industries (see *Appendix-Table 2*).

[6] The coastal region includes Liaoning, Beijing, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, and Guangxi.

- The remaining error tem ε_{it} is a well-behaved unobserved shock ($\omega_{it} \sim N(0,1)$). All time-varying regressors are lagged one year to avoid potential simultaneity problems.

Although the empirical model given by Eq. (1) can properly express the research question of whether innovation will affect a firm's decision to export, this question is different from the question of whether innovation will affect a firm's decision to continue exporting. Our three-year panel includes (1) firms that never export; (2) firms that always export; (3) firms that switch from exporting to non-exporting; and (4) firms that switch from non-exporting to exporting. Van Beveren and Vandenbussche (2010) limit their analysis to firms that begin to export and non-exporters to control for the causality bias and the persistence of firm-level exports. However, this method will make the sample very small and could cause a selection bias. In this paper, we incorporate an interaction term between the lagged export dummy and innovation dummy ($\mathrm{EXP}_{i,t-1} \times \mathrm{INN}_{i,t-1}$) to account for this difference. Moreover, there is no convincing argument that the decision-making function of foreign firms is the same as that of Chinese domestic firms, especially in the high-tech sector. The R&D status for foreign firms operating in China does not reflect the truth as the R&D likely takes place in parent firms operating outside of China; the parent firm can then transfer knowledge internally from the parent firm to affiliates in China. Therefore, it is desirable to differentiate foreign firms from domestic firms in the analysis, so we run the regressions for foreign firms and domestic firms separately. As a baseline regression model we use a pooled probit model to estimate Eq. (1). To control for the possible endogeneity problem, we use an instrumental variable approach and nonparametric matching method in the sensitivity analysis. Moreover, we test the relation between innovation and export participation across the key industries and provinces.

4.2 Data

The data employed in this paper were drawn from China's annual enterprise survey conducted by the National Bureau of Statistics of China (NBSC). This study focused on the enterprises operating in the high-tech sector. Unfortunately, though R&D expenditure was a critical variable in the analysis, it was only reported during the period of 2005-2007. To obtain a 'clean' dataset for the following analysis, we use the following criteria, as Jefferson et al. (2008) and Cai and Liu (2009) did, to remove the outliers and abnormal observations: (1) observations must not have key variables that are missing or negative (e.g., export value, R&D expenditure, new product output, added value); (2) the number of employees must not be less than 8; (3) the firm's total assets must be greater than total fixed assets; and (4) the firm's identification number must be unique and cannot be missing. After cleaning, a balanced panel dataset for 9,972 firms over the period of 2005-2007 was obtained.

Table 3 Export and innovation sequence (2005-2007)

Sequence	Exports	R&D	Product Innovation
000	4,658 [46.7]	5,766 [57.8]	7,095 [71.1]
001	267 [2.7]	560 [5.6]	371 [3.7]
010	117 [1.2]	296 [3.0]	206 [2.1]
011	340 [3.4]	605 [6.1]	344 [3.4]
100	233 [2.3]	363 [3.6]	306 [3.1]
101	131 [1.3]	208 [2.1]	87 [0.9]
110	189 [1.9]	297 [3.0]	166 [1.7]
111	4,037 [40.5]	1,877 [18.8]	1,397 [14.0]
Total	9,972 [100]	9,972 [100]	9,972 [100]

Note: '1-0' denotes a dummy variable (yes=1, no=0). The data in columns 2-4 show the number of firms, with the share (%) over the total in brackets.

Table 3 lists the numbers and percentages of firms in terms of their export and innovation sequences during the sample years. It shows that 46.7% of the sampled firms never exported, whereas this figure is higher for the firms that never invested in R&D (57.8%) or those that conducted product innovation (71.1%). In addition, 40.5% of the 9,972 firms always exported, but only 18.8% of them conducted R&D, and 14% introduced new products. These statistics may reveal that Chinese high-tech enterprises are export oriented but less innovative. The data from the perspective of industry and firm location demonstrate that Chinese high-tech exports tend to concentrate in the electronic and telecommunication equipment industry and the computer and office equipment industry. Together, these two industries account for more than 95% of total exports and 85% of total R&D expenditures of the sample. Furthermore, more than 70% of high-tech exports came from Guangdong, Jiangsu and Shanghai.

4.3 Comparison of exporters and non-exporters

In this sub-section, we compare exporters to non-exporters with respect to their innovation efforts and other firm characteristics, which will enable us to develop an elementary understanding of the relation between innovation and exporting.

Panel A of Table 4 shows that exporters are on average more innovative than non-exporters in the year t-1. Among the exporters, the share of firms undertaking R&D (30.7%) is slightly larger than the share within non-exporters (27.8%). Exporters are also more likely to introduce new products (23.3%) compared to non-exporters (17.8%). However, exporting innovators invested less than non-exporting innovators did in terms of the R&D intensity. Dividing the sample according to the firms' ownership yields similar results, but the differences between exporters and non-exporters within domestic firms (SOEs and non-SOEs) become substantial. Moreover, the average R&D intensity of exporters becomes higher than that of non-exporters within domestic firms.

In Panel B of Table 4, we present the differences in other firm characteristics between exporters and non-exporters. The mean statistics show that exporters are significantly different from non-exporters in terms of other firm characteristics as well. First, exporters are more productive than non-exporters with respect to total factor productivity (TFP). Second, the average firm size of exporters is four times larger than that of non-exporters in terms of the number of employed workers. Finally, exporters are found to be more capital intensive and to pay higher wages than non-exporters. All of these firm characteristics are consistent with findings for other countries.

Table 4 Differences between exporters and non-exporters

	Exporters	**Non-exporters**
Panel A. Innovation efforts (%)		
All firms		
R&D dummy	30.7	27.8
R&D intensity	0.69	0.89
Product innovation dummy	23.3	17.8
Foreign-owned enterprises		
R&D dummy	24.3	21.5
R&D intensity	0.53	0.66
Product innovation dummy	17.5	14.4
HMT enterprises		
R&D dummy	20.0	18.7
R&D intensity	0.31	0.59
Product innovation dummy	11.4	10.3
State-owned enterprises		
R&D dummy	79.2	48.0
R&D intensity	1.74	1.65
Product innovation dummy	75.4	34.8
Non-state-owned enterprises		
R&D dummy	45.6	28.9
R&D intensity	1.21	0.92
Product innovation dummy	38.7	18.3
Panel B. Mean characteristics		
TFP(log)	7.38	6.92
Number of employees	846	212
Capital per worker (log)	3.70	3.53
Average wage (*yuan*)	21,354	18,586
Average age (*year*)	9.7	9.8

Note: All variables are lagged one year.

5. Empirical Results

5.1 The baseline model

The results of the regression of innovation activities on firms' export participation are presented in Table 5. The regression is estimated using a pooled probit model.[7] In the first two columns, firms' innovation efforts are measured by R&D dummies, whereas in the last two columns we use product innovation dummies. All of the values in Table 5 are marginal effects, defined as the marginal probability change at the mean of the independent variables (discrete change from 0 to 1 for dummy variables), and standard errors are reported in parentheses. [8]

The results in column (1) of Table 5 show that firms that undertake R&D in the current year are more likely to export next year compared to current non-innovating firms. The marginal effect of the R&D dummy implies that conducting R&D on average increases the export likelihood by 8.6 percentage points. Similarly, the statistically significant coefficient of the product innovation dummy suggests a positive effect of introducing a new product on the propensity of exporting, as given by column (3). These findings are in line with those reported by Caldera (2010) for Spain. Using a similar empirical framework[9], she finds that firms investing in R&D increase their export propensity by 8.5 percentage points. Firms introducing product innovation exhibit an increase in their likelihood of exporting of 4% points.

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[7] We also estimated a random-effects probit model to control for unobserved heterogeneity, but a likelihood ratio test shows that the firm-level variance component is unimportant, and the panel probit is not different from the pooled probit. Therefore, we reported the results of pooled probit models only.

[8] The interaction effect between innovation and exports is calculated using the Stata module *inteff* developed by Norton et al. (2004).

[9] Caldera (2010) estimated the baseline specification using a random-effect probit model.

Table 5 Estimation results of the baseline model (general manufacturing)

Lagged independent variable	(1)	(2)	(3)	(4)
Innovation dummy	0.086 ***	0.055 ***	0.065 ***	0.059 ***
	(0.012)	(0.016)	(0.014)	(0.018)
Export dummy	0.818 ***	0.809 ***	0.817 ***	0.816 ***
	(0.005)	(0.006)	(0.005)	(0.005)
Innovation*Export		0.026 ***		0.001
		(0.011)		(0.012)
TFP (log)*10^{-5}	0.377 ***	0.365 ***	0.424 ***	0.423 ***
	(0.000)	(0.000)	(0.000)	(0.000)
FIE dummy	0.226 ***	0.229 ***	0.221 ***	0.222 ***
	(0.011)	(0.011)	(0.011)	(0.011)
HHI (log)	0.735 **	0.736 **	0.837 **	0.835 **
	(0.356)	(0.358)	(0.356)	(0.357)
Coastal region dummy	0.072 ***	0.074	0.068	0.068 ***
	(0.016)	(0.016)***	(0.016)	(0.016)
LR test (χ^2)	9.86***		0.23	
Pseudo R^2	0.628	0.629	0.627	0.628
Observations	19,944	19,944	19,944	19,944

Note: The innovation measure in columns (1) and (2) uses an R&D dummy, whereas the innovation measure in columns (3) and (4) uses a product innovation dummy. The coefficients are marginal effects, defined as the marginal probability change at the mean of the independent variable or the discrete change of a dummy variable from 0 to 1. Robust standard errors are reported in parentheses. All regressions include a constant. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

Furthermore, we include an interaction term between innovation and exports in the baseline model to check how the effect of innovation on export participation in the next period differs between current exporters and non-exporters. We performed a likelihood ratio test to evaluate the difference between nested models. The results of a Chi-squared test show that the less restrictive model (i.e., the one with an interaction term between the lagged R&D dummy and the export dummy) fits the data better than the more restrictive model without the interaction term given the level of significant of 5%. However, when we add an interaction term between product innovation and export participation as a predictor variable in the baseline model, the results remain the same. The interaction effect in column (2) shows that current exporters investing in R&D exhibit an increase of 2.6% in their probability to export compared to other groups. Nevertheless, we did not find heterogeneous effects of product innovation on export propensity between current exporters and non-exporters.

With regard to the other firm-level determinants of exporting, the results are consistent with those found in the previous literature. The positive and highly significant coefficient of the lagged export status variable suggests that firms that exported in the current year are about 82 % more likely to export in the following year. This result indicates the existence of sunk entry cost associated with entering foreign markets and is in line with the theoretical prediction of Roberts and Tybout (1997). The positive coefficient of the logarithm of TFP suggests that more productive firms are more likely to export, in line with the prediction of the Melitz (2003) model and a wide range of empirical findings on the export-productivity premium for developed and developing countries reviewed by Wagner (2007). The explanation is based on the existence of fixed costs of exporting, under which only more productive firms could make profits in the export markets.

As to foreign ownership, the coefficients of the foreign-invested enterprises dummy are positive and statistically significant at the 1% level for all specifications. This result suggests that foreign-invested enterprises are more likely to export than domestically-owned enterprises in the Chinese high-tech sector; the probability to export increased by an average of 22%. This result is in line with previous evidence reported for Spain (Caldera, 2010), Thailand (Cole *et al.*, 2010), and China (Huang *et al.*, 2008). The coefficients of HHI are positive and consistently significant in all specifications, which suggest that firms in more concentrated sectors are more likely to export. Besides, firms located in the coastal region of China are more likely to export than those located in inland central or western provinces because the coefficients of the coastal region dummy are positive and highly significant across the different models.

5.2 Foreign-invested enterprises versus domestic firms

The baseline modeling result, namely, innovating firms are more likely to export, is in line with the theoretical prediction proposed by Caldera (2010). However, the dichotomy between domestic firms and foreign-invested firms may be overly simplistic because there is a large degree of variation within each category. It is well documented that foreign-invested enterprises behave quite differently from domestic firms in China.

Table 6 The effect of innovation on export participation by ownership

Lagged independent variable	Foreign firms (1)	Foreign firms (2)	Domestic firms (3)	Domestic firms (4)
Innovation dummy	-0.014	0.002	0.066 ***	0.062 ***
	(0.020)	(0.023)	(0.013)	(0.016)
Export dummy	0.745 ***	0.759 ***	0.825 ***	0.828 ***
	(0.011)	(0.009)	(0.009)	(0.008)
Innovation*Export [a]	0.041 *	-0.001	0.027	0.010
	(0.020)	(0.025)	(0.013)	(0.014)
TFP (log)*10^{-5}	0.262 ***	0.291 ***	0.213 ***	0.258 ***
	(0.000)	(0.000)	(0.000)	(0.000)
HHI (log)	0.005	0.039	0.813 ***	0.898 ***
	(0.352)	(0.351)	(0.313)	(0.315)
Coastal region dummy	0.095 ***	0.095 ***	0.040 ***	0.036 ***
	(0.028)	(0.028)	(0.012)	(0.012)
LR test (χ^2)	9.12 ***	0.001	0.53	0.09
Pseudo R^2	0.516	0.515	0.589	0.587
Observations	19,944	19,944	19,944	19,944

Note: The innovation measure in columns (1) and (3) uses an R&D dummy, while the innovation measure in columns (2) and (4) uses a product innovation dummy. The coefficients are marginal effects, defined as the marginal probability change at the mean of the independent variable or the discrete change of a dummy variable from 0 to 1. Robust standard errors are reported in parentheses. All regressions include a constant. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

In China, foreign firms play a dominant role in high-tech exports. As we reported in Section 2, more than 80 % of Chinese high-tech exports are conducted by foreign firms. At the same time, foreign firms are found to be less innovative than domestic firms. Therefore, the estimations of the pooled specification may be misguided. To avoid aggregation problems, we classify the whole sample into two parts according to firm ownership and then run regressions using the baseline model for foreign firms and domestic firms, respectively.

Table 6 presents the results of the baseline models for foreign firms and domestic firms. Based on the results in columns (1) and (2), we find that innovation efforts do not increase the propensity to export for foreign affiliates in China because the estimated coefficients of R&D and product innovation dummies are not significant at the conventional level. This finding is in line with Huang et al. (2008). They suggested processing trade as an explanation for the phenomenon that foreign firms that are less committed to innovation activities have higher levels of exports.

According to *China Statistics Yearbook on High Technology Industry* (2009), over 85 % of Chinese high-tech exports were accounted for by processing of supplied materials and imported materials in both 2006 and 2007. For most foreign firms, their affiliates usually shipped components and parts to China for assembly to take advantage of the low labor costs there before exporting the final goods overseas. Moreover, many firms act as contractors for other multinationals, like Foxconn, the giant Taiwanese contractor for firms such as Apple and Nokia. For such firms, the influence of innovation activities on the growth of exports is usually minor.

As for domestic firms, the estimation results for innovation dummies are positive and highly significant in columns (3) and (4). The marginal effect shows that domestic firms that undertake innovation activities during the current year are 6 % more likely to export next year compared to those domestic firms that do not innovate. The insignificant coefficients of the interaction term indicate that the effect of innovation does not rely on the lagged export status. The results of likelihood ratio tests also confirm that adding the interaction term between innovation and export participation does not result in a statistically significant improvement in model fit.

6. Further Analyses

6.1 Endogeneity issues

Our previous pooled probit regressions are based on the assumption that our main variables, in particular, firms' innovation participation, are orthogonal to the error term. According to the baseline model, we have mitigated the possible endogeneity problem by using a one-period lag of all major independent variables. However, the lagged innovation dummy may still be endogenous due to the anticipation effect modeled by Costantini and Melitz (2007), in which they proved that firms' innovation activities could be driven by their anticipated entry into the export market[10]. Several authors hence suggest using an instrumental variable (IV) approach to deal with the endogeneity of innovation participation in export decisions (e.g., Nguyen *et al.*, 2008; Van Beveren and Vandenbussche, 2010; Caldera, 2010).

However, the difficulty in applying the IV approach is to identify appropriate instrumental variables, which should be independent of the dependent variable (i.e., the export decision) but correlated with the endogenous regressors (i.e., the innovation decision). The simplest way to achieve this goal is to use the pairwise correlations between any endogenous regressors and instruments (Cameron and Trivedi, 2009, p.189). Therefore, we propose two instrumental variables, namely, worker training and advertisement expenditures, from our dataset. We believe that firm-level worker training activities are correlated with

[10] Huang et al. (2008) argue that "the export success of a firm in a particular year would have little impact on its compensation strategy or R&D activity which was determined one or two years before." Therefore, they did not tackle the potential endogeneity problem of innovation participation.

firm-level innovation activities because skilled workers are required for R&D. The indicator of whether firms spend money on advertisement is an indirect indicator of the market power of the firm. Firms with less market power are more likely to advertise their products, which also leads to an increase in investment in innovation activities.

Both instruments are taken as dummy variables that indicate whether firms normally train their existing workers or hire new workers and whether firms spend on advertisement. Spearman's rank correlation coefficients show that these two instrumental variables are highly correlated with innovation decisions but are not related to firms' export decisions, suggesting that they might be good instruments (see Table 7). The results of simply regressing export decisions on worker training and advertisement indicators also confirm that the two instruments are not directly related to firms' propensity to export.

Table 7 Spearman correlations

	Export	**R&D**	**Product innovation**
Worker training	0.008	0.306	0.232
	(0.238)	(0.000)	(0.000)
Advertisement	0.010	0.369	0.254
	(0.151)	(0.000)	(0.000)

Note: Reported values are Spearman's rank correlation coefficients, and p values are given in parentheses.

Another problem arises because the endogenous regressor, innovation decision, is a binary variable in our baseline model, whereas standard IV probit estimation procedures require the endogenous variable to be continuous. Moreover, nonlinear IV estimation requires a very strong assumption, i.e., that the error terms in the first and second stages are identically normally distributed. We therefore follow Caldera (2010) and Van Beveren and Vandenbussche (2010) in using two-stage least squares (2SLS) to investigate the causal impact of firm-level innovation activities on export propensity.

Table 8 Instrumental variable estimation (2SLS)

Lagged independent variables	Foreign firms (1)	(2)	Domestic firms (3)	(4)
Innovation dummy	0.041 *	0.086 *	0.071 ***	0.147 ***
	(0.016)	(0.036)	(0.011)	(0.022)
Export dummy	0.760 ***	0.759 ***	0.821 ***	0.799 ***
	(0.009)	(0.009)	(0.007)	(0.009)
TFP (log) $*10^{-6}$	0.496 ***	0.388 **	0.499 ***	0.060 **
	(0.000)	(0.000)	(0.000)	(0.000)
HHI (log)	-0.006	-0.004	0.289 *	0.161
	(0.212)	(0.212)	(0.157)	(0.165)
Coastal region dummy	0.061 ***	0.063 ***	0.021 ***	0.026 ***
	(0.016)	(0.016)	(0.006)	(0.006)
Wu-Hausman F test	2.690*	5.387**	18.811***	32.023***
Anderson canon. corr. LR test (χ^2)	1818.56***	480.96***	3152.72***	815.19***
Cragg-Donald Wald F statistics (χ^2)	2023.47***	494.56***	3637.43***	815.20***
Sargan (χ^2)	1.786	2.170	0.138	0.554
R-squared	0.601	0.597	0.683	0.672
Observations	8,665	8,665	11,279	11,279
Instruments (dummies)	Worker training Advertising	Worker training Advertising	Worker training Advertising	Worker training Advertising

Note: The innovation measure in columns (1) and (3) uses an R&D dummy, while the innovation measure in columns (2) and (4) uses a product innovation dummy. Reported values are coefficients (robust standard errors). ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The Wu-Hausman test has the null hypothesis that the regressor is exogenous; Anderson's likelihood ratio test has the null hypothesis that the specified instruments are redundant; the Cragg-Donald test has the null hypothesis that the instruments are weak against the alternative that they are strong; and the Sargan statistic has the null hypothesis that all instruments are orthogonal to the error (i.e., that the instruments chosen are valid).

In Table 8, we present the results of applying an instrumental variable approach to the linear probability model, in which we account for the endogeneity of firms' innovation by instrumenting. The coefficients of the innovation dummy for foreign firms are significant only at the 10% level after controlling for the potential endogeneity. However, it is worth noting that the Wu-Hausman test statistic points to potential exogeneity of innovation activities for foreign-invested firms. One possible explanation is that when multinational firms make FDI decisions, the decisions of export and innovation are determined almost simultaneously. Therefore, there seems to be no causal relation between the innovation and export decisions for foreign firms operating in China. As for Chinese indigenous firms, the results are similar to those obtained from pooled probit models. The coefficients of the instrumented innovation dummy variables are positive and statistically significant.

To test the validity of our instrumental variables, we performed several statistical tests under an LPM framework. [11] The calculated Wu-Hausman test statistic suggests that innovation participation is endogenous in the export decision, especially for domestic firms, lending supporting evidence to the use of IV approach. Anderson Identification (IV relevance) tests support our expectation of the explanatory power of the excluded instruments. In addition, both the Cragg-Donald F-static and the Sargan Chi-square statistic suggest that the proposed instruments are valid.

Table 9 Innovation dummy coefficients (matching estimator)

Average treatment effect	FIEs	Domestic firms
R&D dummy	0.004	0.027***
	(0.009)	(0.006)
Product innovation dummy	-0.005	0.022***
	(0.011)	(0.007)
Observations	8,665	11,279

Note: Matching variables are lagged export status, log (TFP), log (HHI) and a coastal region dummy. Robust standard errors are given in parentheses. *** indicates significance at the 1% level.

In addition to the IV approach, we can make use of a non-parametric matching method to find the consistent average treatment effects of innovation dummy variables on export participation. The matching method compares the outcomes of innovators with those of matched non-innovators, where matches are chosen on the basis of similarity in observed characteristics. One of the main advantages of matching estimators is that they typically do

[11] All test statistics were obtained using the Stata module *ivreg2*, developed by Baum et al. (2004).

not require the specification of the functional form of the outcome equation and are therefore not susceptible to misspecification bias. [12]

The results based on the matching estimators are reported in Table 9. We can see that the effect of innovation on export participation is robust and consistent with the above parametric results. Innovation activities are not a contributing factor to export participation for foreign-invested enterprises. As for domestic firms, past innovating participation is shown to increase the probability of exporting in the future by approximately 2.2-2.7 percentage points, which is a smaller increase than those obtained from the baseline models.

6.2 Evidence of the industry-level and province-level

In this section, we examine the impacts of innovation activities on export participation at the major industry and province levels. Table 10 reports the marginal effects of innovation by industry using the pooled probit model for two industries: electronic and telecommunication equipment manufacturing and computers and office equipment manufacturing. The reason for choosing these two industries is that together they account for 95 % of Chinese high-tech exports and 85 % of innovation investment. According to the results, innovative firms operating in electronic and telecommunication equipment manufacturing are more likely to export compared to non-innovative firms because the coefficients of innovation dummy variables are positive and significant for both foreign firms and domestic firms.

However, the impact of innovation on exporting is different in computer and office equipment manufacturing. Only the marginal effect of the R&D dummy for domestic firms is positive and highly significant. The product innovation dummy even shows a negative sign for foreign firms. This finding may indicate that foreign firms in computer and office

[12] Please see Abadie et al. (2004) and Abadie and Imbens (2006) for details about the matching method and Stata module.

equipment manufacturing introduce new products to explore the host market rather than foreign markets.

Table 10 Marginal effects of innovation dummy by industry

	FIEs		Domestic firms	
	(1) R&D	(2) Product innovation	(3) R&D	(4) Product innovation
Electronic and telecommunication equipment	0.050 *** (0.012) [5988\0.492]	0.027* (0.016) [5988\0.491]	0.104 *** (0.019) [5363\0.577]	0.048 *** (0.020) [5363\0.573]
Computers and office equipment	-0.009 (0.028) [1095\0.454]	-0.104 ** (0.049) [1095\0.458]	0.132 *** (0.053) [516\0.553]	-0.010 (0.062) [516\0.544]

Note: All other variables are controlled in the baseline model. Reported values are marginal effects of the innovation dummy, with robust standard errors in parentheses. The number of observations and pseudo R^2 values are reported in brackets. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 11 Marginal effects of innovation dummy by province

	FIEs		Domestic firms	
	(1) R&D	(2) Product innovation	(3) R&D	(4) Product innovation
Guangdong	0.027 (0.015)*	0.003 (0.022)	0.118 (0.035)***	-0.008 (0.042)
	[3292\0.389]	[3292\0.388]	[1774\0.529]	[1774\0.524]
Jiangsu	0.077 (0.030)***	0.010 (0.061)	0.084 (0.032)***	0.157 (0.057)***
	[1441\0.600]	[1441\0.597]	[1281\0.650]	[1281\0.655]
Shanghai	0.064 (0.034)*	-0.022 (0.048)	0.089 (0.050)*	0.032 (0.070)
	[733\0.502]	[733\0.500]	[403\0.650]	[403\0.641]
Zhejiang	-0.022 (0.037)	0.004 (0.036)	0.065 (0.031)**	0.066 (0.032)**
	[769\0.534]	[769\0.534]	[2399\0.573]	[2399\0.573]
Beijing	0.099 (0.067)	0.026 (0.070)	0.020 (0.028)	0.073 (0.027)***
	[377\0.539]	[377\0.536]	[879\0.525]	[879\0.531]
Tianjin	-0.030 (0.053)	0.061 (0.049)	0.061 (0.072)	0.040 (0.077)
	[321\0.527]	[321\0.530]	[215\0.536]	[215\0.534]

Note: All other variables are controlled in the baseline model. Reported values are marginal effects of the innovation dummy, with robust standard errors in parentheses. The observations and pseudo R^2 are reported in brackets. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

At the provincial level, we can see that innovation activities play little role in foreign firms' export participation. Only the marginal effect of R&D for Jiangsu province was positive and highly significant. Among domestic firms, R&D has a positive impact on export participation for those located in Guangdong and Jiangsu Province, whereas product innovation shows a positive impact on firms located in Jiangsu and Beijing. It can be concluded that innovation activities play some role in export decisions for Chinese domestic firms, but the roles are very uneven across industries and provinces. The role of innovation in foreign firms' export participation remains insignificant or minor.

7. Conclusion

This paper contributes to the debate on the relationship between innovation and high-tech exports in developing countries. Using a large panel dataset from Chinese high-tech firms during the period of 2005-2007, we examine the role of innovation activities in export participation. Following the most recent literature, we use two measures of innovation, that is, R&D and product innovation. We consider the heterogeneous behaviors of domestic-owned and foreign-owned firms when we analyze the relation between innovation and export participation. In addition, we use an IV approach and non-parametric matching techniques to consider the possible endogeneity of innovation in the export decision. Our results suggest that innovation activities play a minor role in the export success of Chinese high-tech exports. We also find that foreign firms dominate Chinese high-tech exports but do not rely on innovation activities in China. Innovation efforts have a positive impact on export participation for domestic firms, but their magnitude is very small. It is shown that the impacts of innovation on export participation vary according to the measures of innovation. Finally, the roles of innovation in high-tech export participation are very uneven across industries and provinces and may correspond to different export patterns.

Our findings are broadly consistent with the idea that the success of Chinese high-tech exports is not determined by individual firms' dedication to innovation activities. Foreign-invested firms account for most of China's high-tech exports but are unlikely to conduct innovation activities in China. Although we find a positive role of innovation in export participation for domestic firms, these firms have not become the main force of high-tech product exports, indicating that the R&D capability remains weak in domestic firms and that their high-tech products are not competitive on international markets. Therefore, policymakers in China must make some policy adjustments to meet the challenge of achieving a competitive advantage in the next few decades. In fact, a variety of policies have been implemented to promote China's high-tech industries since the 1990s. China has been very successful in attracting high-tech enterprises and encouraging high-tech exports, but it has not yet improved the innovative capabilities of domestic firms. Recently, China's central government has adjusted related policies and made efforts to integrate innovation policy with tax policy and trade policy. For example, China increased the tax refund for key scientific and technical equipment, IT products and biological and medical products in 2005. Meanwhile, 150% of the R&D expenses for the development of new technology, products and techniques can be deducted from a firm's tax liability as of 2008. The depreciation term can be shortened or sped up for fixed property that depreciates faster due to technological improvements. However, it will take time to for the impacts of these policy adjustments to become apparent, and China still has a long way to go to transform itself into a knowledge-based economy.

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Appendix

Table 1 The classification of Chinese high-tech industries

Code	Industries
(I)	**Manufacture of Medicines**
2710	Original drug manufacturing chemicals
2720	Chemical agent production
2730	Traditional Chinese medicine processing
2740	Traditional Chinese prepared medicines
2750	Veterinary medicine manufacturing
2760	Biological, chemical and biological products manufacturing
2770	Sanitation materials and medical articles
(II)	**Manufacture of Aircraft and Spacecraft**
3761	Airplane manufacturing and repairing
3762	Spacecraft manufacturing
3769	Other flying objects manufacturing
(III)	**Manufacture of Electronic Equipment and Communication Equipment**
401	Manufacture of communication equipment
4011	Communications transmission equipment manufacturing
4012	Communication exchange equipment manufacturing
4013	Communications terminal equipment manufacturing
4014	Mobile communications and terminal equipment manufacturing
4019	Other communications equipment manufacturing
402	Manufacture of radar and its fittings
403	Manufacture of broadcasting and TV equipment
4031	Radio and television program production and transmission equipment manufacturing
4032	Radio and television receiving equipment manufacturing
4039	Application of television broadcasting equipment and other equipment
405	Manufacture of electronic appliances
4051	Electronic vacuum device manufacturing
4052	Semiconductor manufacturing discrete devices
4053	Integrated circuit manufacturing
4059	Optoelectronic devices and other electronic device manufacturing
406	Manufacture of electronic components
4061	Electronic components and parts manufacturing
4062	Printed circuit board manufacturing
407	Manufacture of domestic TV sets and radio receivers
4071	Home video equipment manufacturing
4072	Home audio equipment manufacturing
409	Other electronic equipment manufacturing

(IV)	**Manufacture of Computers and Office Equipment**
404	Manufacture of computers
4041	Integrated computer manufacturing
4042	Computer network equipment manufacturing
4043	Computer peripheral equipment manufacturing
415	Manufacture of office equipment
4154	Photocopying and offset equipment manufacturing
4155	Calculator and money for equipment manufacturing
(V)	**Manufacture of Medical Equipment and Meters**
368	Manufacture of medical equipment and appliances
3681	Medical diagnosis, care and treatment equipment manufacturing
3682	Dental equipment and apparatus manufacturing
3683	Laboratory and medical equipment and apparatus disinfection system
3684	Medical, surgical and veterinary equipment manufacturing
3685	Treatment and nursing mechanical equipment manufacturing
3686	Artificial organs and plantations (referred) to enter devices
3689	Other medical equipment and device manufacturing
411	Manufacture of general measuring instruments
4111	Industrial automation system device manufacturing
4112	Electrical instrument manufacturing
4113	Mapping, calculation and measurement equipment manufacturing
4114	Experimental analysis of equipment manufacturing
4115	Testing machine manufacturing
4119	Supply with general instruments and other equipment manufacturing
412	Manufacture of special measuring instruments
4121	Environmental monitoring instrumentation for manufacturing
4122	Auto and other counting meters and instruments manufacturing
4123	Navigation, meteorology and marine equipment for manufacturing
4124	Special instruments and meters for agriculture, forestry, animal husbandry and fisheries
4125	Geological exploration and seismic equipment manufacturing
4126	Teaching special equipment manufacturing
4127	Nuclear and nuclear radiation measurement
4128	Electronic measuring equipment manufacturing
4129	Other special equipment manufacturing
4141	Optical equipment manufacturing
4190	Other instrument manufacturing and repair

Table 2 Estimated production function coefficients, Levinsohn-Petrin estimation

Industry	Capital (lnK)	Labour (LnL)	CRS test (Wald test)	CRS test (p-value)
Pharmaceuticals	0.103	0.187	388.61	0.000
Aircraft and Spacecraft	0.270	0.128	8.90	0.003
Electronic and Telecommunications Equipment	0.153	0.173	1626.38	0.000
Computers and Office Equipment	0.148	0.246	172.84	0.000
Medical Equipment and Meters	0.117	0.157	626.45	0.000

Note: The dependent variable is logarithm of real value added.

CRS test on constant return to scale

Table 3 Definitions of ownership dummy variables

Ownership Dummy	Code	Ownership Category
FOE	**Foreign-owned Enterprises**	
	310	Foreign joint ventures
	320	Foreign cooperatives
	330	Foreign wholly-owned enterprises
	340	Foreign shareholding limited companies
HMT	**Hong Kong, Macau, Taiwan-owned Enterprises**	
	210	Overseas joint ventures
	220	Overseas cooperatives
	230	Overseas wholly-owned enterprises
	240	Overseas shareholding limited companies
SOE	**State-owned Enterprises**	
	110	State-owned enterprises
	141	State-owned jointly operated enterprises
	143	State-collective jointly operated enterprises
	151	Wholly state-owned companies
Non-SOE	**Non-state-owned Enterprises**	
	120	Collective-owned enterprises
	130	Shareholding cooperatives
	142	Collective jointly operated enterprises
	149	Other jointly operated enterprises
	159	Other limited liability companies
	160	Shareholding limited companies
	171	Private wholly-owned enterprises
	172	Private cooperative enterprises
	173	Private limited liability companies
	174	Private shareholding companies
	190	Other enterprises

Note: FOEs and HMTs are classified as foreign-invested enterprises (FIEs), while SOEs and Non-SOEs are considered as domestic firms in the analysis.