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Technology imports, product exports and firms' R&D investment: an empirical analysis of firms in the Chinese high technology sector

Cindy Millman[a]*, Zhengwei Li[b] and Renyong Chi[b]

[a]*Birmingham City Business School, Birmingham City University, Birmingham, UK;* [b]*College of Business Administration, Zhejiang University of Technology, Hangzhou, China*

New trade theory emphasises the important role that international trade plays in advancing technologies. This study examines the impact of international trade on firm research and development investment (RDI). Specifically, it analyses the impact of technology imports and product exports respectively on firm RDI in the high technology sector of China. The hypotheses are tested against 1111 firms in the high technology sector in Zhejiang province. Neither technology imports nor product exports have a positive impact on firm RDI at an aggregated level. However, disembodied technology imports have a significant positive impact on firm RDI, while non-high technology product exports show a significant negative impact.

Introduction

Technological innovation is becoming a critical source of competitive advantage (Porter, 1990; Galende Del Canto and González, 1999) and is increasingly regarded as the driving force of a modern economy (Sun *et al*., 2009). In line with this, knowledge and technology are now recognised as key ingredients underlying the competitiveness of nations, regions, sectors and firms (Romer, 1986, 1990; Nonaka and Takeuchi, 1995; Grant, 1996). Specifically, they have become vital elements that determine competitive advantage and, subsequently, a country's position in the new international division of labour (Castells, 1985; Dosi *et al*., 1990; Dicken, 1998; Mascitelli, 1999). Hence, the knowledge development capabilities of economies are increasingly associated with, and embedded within, a nation's systems of innovation (Nelson and Rosenberg, 1993; Freeman, 1995; Cooke *et al*., 2004) and are becoming one of the top priorities on policy agendas around the world.

Innovations in product or process technologies have generally been thought to originate from in-house research and development (R&D) activities. Consequently, firms have invested significant resources in R&D to promote their positions in national and international competition (Malecki, 1987, 1997), although this has typically been within developed and industrialised nations, where more resources are made available for R&D. Developing countries, on the other hand, have been assumed to be technologically dependent on advanced countries, with imported

*Corresponding author. Email: Cindy.millman@bcu.ac.uk

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technologies being their primary sources of innovation (Dunning, 1993; Caves, 1996). However, more recent studies argue that industrial enterprises in developing countries, such as India and China, do create their own technologies and have striven to become technologically independent from developed countries (Katrak, 1998; Lu, 2000; Lu and Lazonick, 2001; Katz, 2001). Against such a background, the determinants of in-house R&D investment (RDI), particularly in developing countries, are becoming attractive research topics. In this paper, we examine two determinants of firms' RDI: the importation of technologies and the export of products.

Studies of RDI and knowledge spill-overs have recently been augmented by the inclusion of international trade (imports and exports) as an alternative, or complement, to inward RDI as a driver of productivity growth (e.g. Chuang and Hsu, 2004; Branstetter, 2006; Wei and Liu, 2006). Therefore, inward RDI, imports and exports can all be seen as channels for knowledge spill-overs (Grossman and Helpman, 1991; Blomstrom and Kokko, 1998; Xu, 2000; Liu and Buck, 2007). They provide firms, especially those in the developing and less developed countries, with opportunities for maturing their innovative capabilities, knowledge and experiences, as well as for learning, catching up with and surpassing advanced world technology and economy levels (Wu, 2008). As a result, a considerable body of literature in China (e.g. Shen and Geng, 2001; Jiang, 2002; Zhang, 2005; Wang *et al*., 2006) has analysed from various perspectives the general impact of inward RDI on Chinese economic development, productivity growth and technological advances. In contrast, however, few studies (Lee, 1996; Zhao and Li, 1997; Fan and Hou, 2007) have devoted attention to the impact of technological spill-overs on firms' RDI through technology imports and product exports. Particularly, there are mixed findings regarding the relationships between firms' international trade and in-house RDI. For example, according to Cohen and Levinthal (1989), Rosenberg (1990) and Bell and Pavitt (1997), the primary purpose of firms' internal R&D in developing nations is to support transfers from developed nations. In contrast, Sun (2002) purports that in-house R&D, rather than imported technologies, is the primary source of industrial innovation in China. Further research is therefore needed to extend understanding in this field. In this paper, we aim to investigate these relationships in firms in the high technology sector within China in order to increase knowledge of Chinese innovation landscapes in the new knowledge-based economy (Hoffman *et al*., 1998).

Research setting

This study investigates the impact of firms' international trade activities on their RDI within the Zhejiang Province in China. The rationale for conducting the study in the context of such a transitional economy is fourfold. First, in the last two decades a large number of studies within both developed and developing countries have made efforts to identify the various factors that impact upon innovation and R&D activities (Cohen, 1995; Kumar and Siddharthan, 1997; Fritsch and Meschede, 2001; Furman *et al*., 2002; Roper and Love, 2002; Sinani and Meyer, 2004; Kumar and Aggarwal, 2005; Becheikh *et al*., 2006; Liu and Buck, 2007). However, there are discrepancies between developed and developing nations, and even among developing nations, in terms of national resources, economic and technological conditions. Further in-depth research is still needed to ascertain whether the research findings from these countries can be applied to the unique context of China. Hence, one of the goals of this study is to extend existing findings to China.

Second, at micro level, there is a lack of research within the proposed fields; in particular, there are few empirical investigations at firm level (Zhu and Li, 2006; Fan and Hou, 2007; Jin *et al*., 2008). The lack of such research does not match the rapid economic development of China, specifically growth in technology imports and product exports. Since China's economic reform and the Open Door policy of the late 1970s, there has been significant growth in international trade activities, in both technology imports and product exports. Total technology imports rose from \$US116 million in 1980 to \$US25,415 million in 2007. Similarly, total product exports reached \$US1217,780 million in 2007 compared with just \$US18,120 million in 1980 (Jin *et al*., 2008; National Bureau of Statistics Commission, 2008; Ministry of Commerce, 2008; SSB, 2008).[1] With growth in technology imports and product exports set to continue, further research is needed to develop knowledge of the relationships among technology imports, product exports and innovation capacity.

Third, at macro level, China's ambition of becoming an 'innovation-oriented country' by 2020 has drawn world attention (*Xinhua News*, 2006). Five criteria have been developed as benchmarks to measure and evaluate this strategic goal. These are: (1) the RDI/gross domestic product (GDP) ratio should be more than 2.5%; (2) the ratio of science and technology contribution to GDP should be more than 60%; (3) the foreign technology dependence level should be less than 30%; (4) the number of patents issued should rank in the world's top five; (5) the number of science and engineering academic papers Chinese researchers publish, and the number of citations to their papers in international journals, should also rank in the world's top five. The strategic goal for 2020 indicates that China's science and technology capacities have been developing rapidly in recent years, which could possibly justify a further strategic goal – to become the world's leading science power by 2050. From these strategic goals, it is clear that the Chinese government would like to see the country transformed into an innovation-oriented country in the not too distant future. Hence, the notion of 'indigenous innovation' has been made a cornerstone of the country's future development (Xie and Li-Hua, 2009). Achieving indigenous innovation requires emphasis on firm RDI. Although the trend suggests that the volume of technology imports is growing rapidly, little is known about what impact this has on firm RDI.

Baldwin and Hanel (2003) propose that RDI is one of the most important mechanisms for determining the overall level of innovation in a given sector or industry. Subrahmanya (2005) argues that, by allocating resources to R&D in sectors of the highest technological intensity, innovation is stimulated. Against this background, we focus our examination on the high technology sector in one province of China with the propensity to generate sample similarity, since R&D is likely to vary across sectors (Tomiura, 2007). The majority of existing studies focus on examining the determinant, international trade (Sterlacchini, 1999; Roper and Love, 2002; Tomiura, 2007) and generally view the importation of technology and the exportation of products at an aggregated level without distinguishing them. The only exception to this is the study of Kumar and Aggarwal (2005), which analyses the dissimilar technology imports using the Indian manufacturing sector's experience.

It is proposed that in the context of China, given its social and economic background, dissimilar types of technology imports (disembodied and embodied) and product exports (high technology and non-high technology) might have different effects on firms' innovation activities, specifically RDI. This suggests the need to examine empirically such relationships in China by separating the different types of technology imports and product exports, providing the opportunity to compare and contrast findings from other countries and, ultimately, to provide the Chinese government with both practical advice and policy implications to support innovation. Consequently, this study yields insight into how internal and external knowledge sources interact with a firm's in-house R&D efforts and hence contribute to the further understanding of the interactions between international trade and innovation.

Specifically, the research is conducted in 1111 high technology firms in Zhejiang province, one of the most advanced provinces in China. Existing literature on technology imports, product exports and innovation fields is reviewed and synthesised before hypotheses are derived. These hypotheses are then tested against data from the firms collected between 2003 and 2005. Two objectives therefore form the basis of this study: (1) to examine the impact of disembodied and embodied technology imports on firm RDI; (2) to investigate the impact of high technology and non-high technology related product exports on firm RDI. On the basis of this empirical examination, an innovation policy recommendation for the Chinese government is proposed for supporting, promoting and developing indigenous innovations.

Technology imports and firm RDI

Technology imports are seen by many firms, especially those in developing countries, as one of the most important channels for generating in-house knowledge and technology. Adopting a low-cost strategy, firms in developing countries can position themselves as market followers to realise cost efficiency. Connolly (2003) concludes that the importance of imports for the diffusion of technology is greater for developing countries than for developed countries. Firms in developing countries can benefit from advanced technology with minimum investment in time and capital. Moreover, firms can digest, absorb and adapt the technologies, adopting them in their own specific contexts, developing new products or adding enhancements to existing products or services and thereby innovating.

Kumar and Aggarwal (2005) separate technology into embodied and disembodied technology. Embodied technology generally refers to technology in the form of capital goods, including knowledge incorporated in plant and machinery. Disembodied technology refers to technology in the form of patents, drawings and designs, and maps that often come with project designs. Few other studies relating to technology imports concern the nature of the technologies being imported. They focus mainly on whether these technologies are core technologies. In this study, the concern is different; it is argued that firms in developed countries would not consider transference or spill-over of core technologies to developing countries. From the perspective of developing countries, as long as the technologies imported are an advance on their own, and are appropriate for application to their products and processes after adaptation, the spill-over is perceived as beneficial. Such technology spill-over could help to reduce the technology gaps between developing and developed countries. More importantly, technology imports will stimulate and promote technological advances, leading to economic and productivity growth (Lin and Zhang, 2005; Wu, 2008).

In recent years, a large volume of research has devoted its attention to examining the relationships between technology imports and firm RDI. The general opinion is that there are either complementary or substitutional effects (Lee, 1996). The complementary view considers technology imports to be an important source of international technology and knowledge spill-overs. Through technology imports, firms are afforded opportunities to learn by doing. This learning process is crucial for late comers seeking to upgrade their technology base and climb the development ladder (Amsden, 1989; Kim and Nelson, 2000; Narula, 2002; Hu *et al*., 2005; MacGarvie, 2006). Hence, it is perceived that technology imports will impact on a host country's innovation at an overall level. Freeman and Soete (1997) argue that at firm level, by only imitating the advanced technology imported, firms are required to have 'threshold competence' to understand and operate the technology. For example, domestic firms can acquire advanced technologies by reverse engineering the products of their foreign suppliers or competitors. The technology imports can act as catalysts in these firms, as often firms need to conduct further R&D to aid their understanding of these technologies. Technology imports therefore lead to the encouragement of firm R&D efforts (Liu and Buck, 2007). Moreover, further R&D activities are often necessary to digest, absorb and adjust imported technologies, so that they can be applied and adapted to the domestic marketplace (Desai, 1980; Leonard-Barton, 1995; Kim, 1997).

In contrast, the substitutional view, which often emanates from the perspectives of cost and risk, is that firms select either to import technology or to develop it internally through R&D. It is argued that in those firms that are heavily reliant on technology imports, specifically from developed nations, the effect can be reduced motivation and demand for internal R&D (Pillai, 1979). This, in turn, can crowd out the firm's own R&D efforts and have a substitutional effect on its R&D activities and innovation capacities (Lee, 1996; Aggarwal, 2000). The level of international technology transfer may also depend on the absolute technological level or absorptive capacity of firms in the host countries (Glass and Saggi, 2002; Durham, 2004). For firms to understand and utilise the technology imported, they need absorptive capacity and threshold competence (Cohen and Levinthal, 1989; Patel and Pavitt, 1994). However, it can be difficult for firms to fully absorb and appreciate certain knowledge, in particular tacit, implicit knowledge. As a result, imported technology may substitute for, rather than promote, local R&D.

There is little agreement on the relationships between technology imports and firm RDI (Aggarwal, 2000). Mixed findings are equally evident in China, where similar debates exist as to whether technology imports have substitutional or complementary effects. The research of Jin *et al*. (2008) finds no evidence to suggest that technology imports have effectively promoted firm RDI. Similarly, Sun *et al*. (2009) find little evidence of the complementary effect of technology imports on firm RDI. Studying large and medium-sized enterprises in the Shanghai region, Zhu and Li (2006) discover that technology imports have mixed effects on both the productivity and the technology capabilities of domestic firms. They contend that technology imports have a significant positive impact on state-owned enterprises, but that there is no evidence to suggest a similar significant effect on other types of enterprise. In contrast, Liu and Buck (2007) propose that technology imports do have a significant impact on the innovation of firms. Moreover, Wu (2008) argues that there is a positive relationship between technology imports and firm productivity. Ke (2009) argues that most of these inconsistent findings are possibly attributable to methodological problems. For example, some researchers use both technology imports and RDI as independent variables (Jin *et al*., 2006; Zhang and Feng, 2007), whereas others use logit models to examine the relationships, neglecting the lagged effect of technology imports on firm RDI.

Inconsistent findings might also arise from the examination of technology imports only at an aggregated level, ignoring the effects that dissimilar types of technology imports might have on firm RDI. Because of the difficulties of obtaining detailed statistics, most studies that explore the relationships between technology imports and firm RDI in China are at an aggregated level. To the best of our knowledge, there has been no research that separates technology imports into different types, nor any that examines the impact of types of technology imports on firm RDI. Kumar and Aggarwal (2005) find that embodied technology imports have a significant positive impact on firm RDI, while this positive impact is absent with disembodied technology imports. Although both India and China are developing countries, research findings from India cannot necessarily be applied to China. For example, Khanna (2008) uncovers the fundamental differences between the two fastest growing economies, based on his personal experiences and a selection of interviews. He suggests that development in China is state-led while in India it is mainly private-led.

This paper presents three basic arguments. First, the advanced knowledge and technology in embodied technologies is often tacit and implicit. Many firms in China lack threshold competence in absorption. Firms often overlook this problem when importing technology and find difficulty absorbing the knowledge (Huchet, 1997; Sun, 2002). For example, firms in China tend to fall into the 'import-lagged import again' trap (Tang, 1999; Li and Zhu, 2004). That is, firms often import technology without fully appreciating the advanced technology and making appropriate applications to their products and processes. As time moves on, firms assume the imported machinery must be lagging behind and providing little advantage over competitors. So, they start the import process again. If firms fall into such a trap, it is unlikely that the technology imports, and the way they are handled, will increase their in-house technology capability. We consider this might be the case in China.

Second, in 2002, Chinese expenditure on technology imports in proportion to absorptive capabilities was 100:7 (i.e. for every 100 yuan spent on technology imports, only 7 yuan were invested domestically in the analysing, learning and absorbing of the technology; Li and Gu, 2005). Moreover, Tang (1999) finds that only 9.2% of project-based imported technology was being absorbed across a total of 2300 projects approved by the Ministry of Science and Technology. Less than 2% of these firms actually formed partnerships with research institutions in order to absorb and apply the technologies in their production. Therefore, it is proposed that in China the import of embodied technology might not have a positive impact on firm RDI and might even crowd out firms' own R&D efforts. Third, disembodied technology imports are often explicit. Compared with embodied technology imports, disembodied imports might be more easily learnt and absorbed by firms in host countries (Robinson, 1988; Cooper, 1994). Hence, they are more likely to encourage and promote the RDI of these firms. Therefore, consistent with the above discussions, the following hypotheses are posited: that disembodied technology imports have a positive impact on firm RDI, and that the positive impact of embodied technology imports is absent and might emerge as a negative sign on firm RDI.

Product exports and firm RDI

Product exports are also considered a key channel for technology spill-overs (Liu and Buck, 2007). Selling in export markets may stimulate firms to improve their own technological capacity (Westphal, 2002). Moreover, domestic firms may benefit from foreign customers in various ways (Blalock and Gertler, 2004). Exporting can therefore be associated with innovation, as exporters are likely to come across diverse knowledge about competing products (Salmon and Shaver, 2005). There are various reasons for this positive impact. First, exporting will probably expand a firm's market, making increased returns from their associated R&D inputs likely. In turn, this will encourage firms to make more investment efforts in their R&D (Zimmerman, 1987; Galende Del Canto and Suárez González, 1999). Second, by interacting with foreign buyers, intermediaries and other agents, exporters are likely to access diverse information at an early stage. Discovering customer preferences through direct feedback will facilitate innovations (Evenson and Joseph, 1997; Salmon and Shaver, 2005). The third explanation is that, in order to meet the preferences and product standards of foreign customers, exporting firms are likely to take initiatives to improve their product designs and quality, which will often require more R&D (Kumar and Saqib, 1996; Liu and Buck, 2007). Blalock and Gertler (2004) argue that compared with non-exporters, exporters are more exposed to the intense competition of the international marketplace. Non-exporting firms may be safeguarded from such competition by trade and geographical barriers. In such a competitive international environment, exporting firms may find it difficult to survive or compete without adopting best-practice or advanced technology by investing in R&D.

Although most research supports the view that there is a positive relationship between exporting and firm R&D, there is little empirical evidence to support this relationship in developing countries. In fact, quite the opposite. Some argue that there are constraints to supporting innovation through exports in developing countries, in that their competitive advantage lies in their traditional manufacturing sector, which has relatively slow growth patterns. Global trade liberalisation has only boosted this competitive advantage, resulting in firms in developing counties being at the lower end of the global value chain (Grossman and Helpman, 1991; Zhang, 2008). Others argue that exports are associated with firms' learning abilities. The argument is that, if a country has not yet reached an appropriate economic level, the pulling force of the exports might have little effect on technological advances and R&D capacities. Only when the technology and economic gap is moderate can domestic firms harvest the benefits from exporting and learning by doing (Kokko *et al.*, 1996).

In the context of China, Zhao and Li (1997) have found that there is a complementary relationship between exports and firm R&D. Similarly, Liu and Buck (2007) conclude that exports promote firm innovation performance. However, Zhang (2008) suggests that there is no positive relationship between exports and firm RDI and even hints at a possible negative effect. From a slightly different perspective, Li and Zhu (2004) propose that different relationships exist because of firms' own capacities and regional economic development levels. For example, their study suggests that the impact of various exports in different regions of China is attributable to the economic disparities in the east, middle and west of the country. We just do not know whether exports promote indigenous innovation. This study extends research in this area with a different approach. It will focus on the international competitive environment of high technology and non-high technology product exports, examining their respective impacts on firm RDI.

High technology products in China come mainly from developed and industrialised countries, such as the United States, European countries and Japan. Coincidentally, these countries are often also China's major export destinations. Because these countries have competitive advantages in their technologies and impose strict standards on imports, high technology products in developed countries may be cheaper than in China. Exposed to such intense competition, Chinese firms look to increased R&D effort. Moreover, interactions with foreign clients (suppliers, retailers and customers), competitors, intermediaries and other agents provide these firms with access to new technologies and information. These firms are therefore more likely to be able to benefit from cross-border international knowledge spill-overs and to improve and enhance their R&D capacities.

The situation with regard to non-high technology product exports suggests a different scenario. In general, the technologies associated with traditional products have matured, so the competitive advantage of such products lies in the ability to control costs. For Chinese firms, the competitive advantage generally comes from exceptionally low costs as a result of using cheap labour. While this can be perceived as a competitive advantage in the international market, these lower costs are homogeneous factors in the domestic market. Hence, the competition level is relatively high. The price of traditional non-high technology products in the domestic market is generally low, because there is little technological development need for non-high technology products and cost is a critical success factor in the international market. The result may be that exporting firms reduce their R&D. In conducting this research, 20 business managers were interviewed. Eighteen of the respondents indicated that their non-high technology exports are mainly for expanding markets and not for seeking technology spill-overs, which is in line with the argument proposed. Consistent with the discussions above, the following hypotheses are proposed: that high technology product exports have a positive impact on firm RDI, and that non-high technology product exports have a negative impact on firm RDI.

Methodology

Sample and data collection

The sample of the study was obtained from firms in the high technology sector in Zhejiang province in China. Data come from an online survey of 1722 firms conducted by the researchers, in collaboration with the Department of Science and Technology of Zhejiang Province (DSTZJ) in 2006, and cover the years 2003–2005. The data were reviewed and nonsensical values deleted, leaving 1111 valid responses. The firms are in various high technology industrial sectors, namely:

- Information communication and technologies (123, 11.1%).
- Pharmaceutical and medical (114, 10.3%).

- New materials (320, 28.8%).
- Electronic machinery and equipment (532, 47.9%).
- New energy and Others (22, 2.0%).

There are also different types of ownership patterns among the firms, with 78.1% being private firms (868), 13.1% *3Zis*[2] (145) and 8.8% (98) state-owned firms. Possible non-response bias was examined by comparing the sales volumes in the 2005 survey of valid responses against non-responses (1111; n=607)[3]. A one-way analysis of variance shows that sales volumes in 2005 between the valid responses and the non-responses are not significantly different (F=0.934, p>0.10). Hence, no significant sample bias exists.

Variables and measures

According to the hypotheses discussed and proposed in the previous section, the dependent variable in this study is RDII, which represents firm internal R&D investment (innovation) level (see Table 1). The explanatory variables are IMPEM, IMPDIS, EXPHIT and EXPTR, which respectively represent activities for: imports of embodied technology, imports of disembodied technology, exports of high technology products and exports of non-high technology (traditional) products. Some additional control variables are also included, namely, TECHDO, PROFIT, DEBT, CAPII, SIZE and HUMAN, which represent technology purchased domestically, profit, debt and liabilities, capital intensity, firm size and human resources, respectively.

Ownership patterns and year are also included in the examination:[4] namely, OWNERST, OWNERPR, OWNERFO and YEAR04 and YEAR05. The first three dummy variables represent state-owned enterprises, private enterprises and *3Zis*,

Table 1. Variables definition and measurement (% unless otherwise specified)

Variable	Explanation
Dependent variables	
RDII	Total private R&D investments by a firm as a proportion of its sales
Independent variables	
IMPEM	Imports of capital goods (including equipment) by a firm as a proportion of its sales
IMPDIS	Royalties and technical fees paid abroad by a firm as a proportion of its sales
EXPHIT	Exports of high technology products by a firm as a proportion of its sales
EXPTR	Exports of non-high technology products by a firm as a proportion of its sales
Control variables	
TECHDO	Royalties and technical fees paid domestically by a firm as a proportion of its sales
PROFIT	Profit (before tax) by a firm as a proportion of its sales
DEBT	Liability of a firm as a proportion of its total asset
CAPII	Total asset of a firm as a proportion of its output
SIZE	Total sales (1000 yuan) of a firm annually (transformed into logarithms)
HUMAN	Total number of scientists (human resources) as a proportion of every 100 employees

Note: Ownership and year dummy variables are not included.

Table 2. Descriptive statistics and correlation matrix (observation n=2222)

Variables	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11
1. RDII	4.034	4.369	1										
2. IMPDIS	.217	1.369	.064***	1									
3. IMPEM	.372	3.512	.002	.038*	1								
4. EXPHIT	11.549	21.302	−.031	−.028	−.003	1							
5. EXPTR	4.653	12.703	−.106***	−.012	−.002	.164***	1						
6. TECHDO	.245	1.196	.086***	.053**	.016	−.003	−.014	1					
7. GOVSU	.453	1.580	0.326***	.007	.046**	.041*	−.055***	.092***	1				
8. PROFIT	12.534	11.815	.089***	.025	.011	.031	−.051**	−.019	.098***	1			
9. DEBT	51.629	35.840	−.042**	.010	.005	.002	.037*	.004	−.043**	−.152***	1		
10. CAPII	2.402	40.714	.109***	.045**	−.002	−.017	−.013	−.006	−.004	−.014	.000	1	
11. SIZE	4.834	.645	−.279***	.048**	.017	.181***	.167***	−.035*	−.173***	−.029	.083***	−.053**	1
12. HUMAN	12.594	13.286	.252***	−.027	.020	−.121***	−.140***	.025	.123***	.018	−.078***	−.017	−.288***

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.
Note: Industry, ownership and year dummy variables are not included.

respectively; while the latter two dummy variables represent firm RDI in 2004 and 2005. The detailed explanations of these variables are presented in Table 1. The adoption of a lagged explanatory approach in this study (this will be explained in more detail in the next section) means that, although the dataset covers a three-year period from 2003 to 2005, only two dummy variables are needed for the years 2004 and 2005.

Two-way causality problem

With regard to the explanatory factors described above, it is recognised that there could be problems of two-way causality. For instance, the theoretical technology imports and product exports of firms are likely to influence R&D. In turn, however, the intensity of technology imports and product exports might also depend on firm R&D (Kumar and Aggarwal, 2005; Liu and Buck, 2007). Similarly, there could also be problems of two-way causality in the relationships between firm R&D efforts and other variables, for example, the intensity of their domestic purchases of technology, level of profits and human resources. Econometric estimates of the various explanatory variables on firm R&D investment are therefore likely to be subject to simultaneity bias. If there is a reverse causation running from R&D to technology imports or product exports, the estimation of a single equation for R&D investment using the ordinary least squares method will lead to inconsistent results (Liu and Buck, 2007). Kumar and Aggarwal (2005) address the causality issue by regressing the R&D intensity on lagged explanatory variables, a technique also used by Katrak (1997). We adopt the same approach here (i.e. the causality issue is addressed by regressing the RDII on the lagged explanatory variables and estimating their impacts on firm RDII). Since there are 1111 firms with three years' data, by regressing the RDII on lagged explanatory variables, the hypotheses are finally tested, with the dataset consisting of 2222 observations. Table 2 presents the correlations matrix with the descriptive statistics for the explanatory and control variables.

Empirical results and discussion

The mean value of the R&D intensity (RDII) is 4.034% (Table 2), which is much greater than that of the larger sized firms in Zhejiang province, and also the national level, for the same period of time. For 2004, the average R&D intensity of large and medium-sized firms in the region, across all industries, is 0.67% and 0.71%, respectively. Although these figures rise to 0.77% and 0.76% in 2005 (SSB, 2008), they are still relatively low. This result indicates that innovation activities and intensity in firms in the high technology sector are greater than in other industries in the region.

Table 2 also shows that the total exports intensity (TOLEXP) in the high technology firms in the region is 16.202%. This is the sum of the high technology product exports intensity (EXPHIT; 11.549%) and the non-high technology product exports (EXPTR; 4.653%). However, EXPHIT (high technology products) at 11.549% is much greater than EXPTR (non-high technology), which is only 4.653%. This result is considered to be strongly associated with the fact that the survey samples are all firms in the high technology sector. The total technology imports intensity (TOLIM) is 0.589% and is the sum of the embodied technology

Table 3. Regression results (observation n=2222)

Variables	Estimation 1 (linear)	Tobit 1	Estimation 2 (linear)	Tobit 2
TOLIM	.030(.025)	.034(.026)		
IMPDIS			.227*(.127)	.243*(.128)
IMPEM			−.245e-2(.017)	.172e-3(.017)
TOLEXP	−.105e-2(.301e-2)	−.210e-2(.334e-2)		
EXPHIT			.073e-1*(.041e-1)	.087e-1**(.043e-1)
EXPTR			−.014***(.457e-2)	−.021***(.599e-2)
TECHDO	.203**(.099)	.214**(.103)	.191*(.100)	.201*(.104)
GOVSU	.687***(.077)	.724***(0.081)	.680***(.077)	.715***(.081)
PROFIT	.023**(.011)	.023*(.013)	.021*(.011)	.022*(.013)
DEBT	.139e-2(.170e-2)	.202e-2(.177e-2)	.141e-2(.171e-2)	.206e-2(.178e-2)
CAPII	.025***(.860e-3)	.025***(.083e-2)	.024***(.946e-3)	.025***(.093e-2)
SIZE	−1.136***(.186)	−.983***(.194)	−1.145***(.187)	−.993***(0.195)
HUMAN	.053***(.011)	.055***(.012)	.053***(.011)	.055***(.012)
OWNERFO	.538*(.314)	.556*(.345)	.599*(.314)	.620*(.344)
OWNERPR	.484**(.244)	.556**(.271)	.532**(.246)	.613**(.272)
Constant	7.803***(1.018)	6.750***(1.072)	7.780***(1.018)	6.727***(1.072)
R^2	0.221		0.255	
Log Likelihood		–5996.41		–5986.52

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.
Note: Industry and year dummy variables are not included.

imports (IMPEM; 0.372%) and the disembodied technology imports (IMPDIS; 0.217%). IMPEM (for embodied technology) is considerably greater than that of IMPDIS (for disembodied technology), which is 0.217%. This suggests that the technology imports for these firms in high technology sectors in the Zhejiang province are more inclined to the 'hard' technology imports, such as machinery and plant types.

As Table 2 shows, there is no evidence in the correlation matrix to suggest the existence of multi-collinearity, and this can be concluded from two perspectives. First, the highest value is –0.288 (HUMAN); second, the variance inflation factors are all less than 2.50. Moreover, the Breusch Pagan test rejected the hypothesis of homoscedasticity. In the absence of knowledge of the precise form of heteroscedasticity, it was decided to report the estimates after correcting the covariance matrices by White's consistent estimator (Greene, 1990). The results of Estimation 1 and 2, and the tobit regression models (Tobit 1 and 2) are presented in Table 3. In Table 3, Estimation 1 and Estimation 2 are the estimates after correcting the covariance matrices by White's consistent regression estimator. The technology imports and product exports are first estimated at an aggregated level, as shown in Estimation 1; they are then sub-divided into disembodied and embodied technology imports, and high technology and non-high technology product exports, as illustrated in Estimation 2. Because 197 observations out of the 2222 have no R&D investment reported at all, the tobit regression was also used to provide more precise results.

Empirical results as shown in Table 3 suggest that, although both coefficients associated with total imports (TOLIM) in Estimation 1 and Tobit 1 are positive (0.030, 0.034), they are not at a significant level. This result supports the statements made by both Jin *et al*. (2008) and Sun *et al*. (2009) when exploring the relationship between technology imports and firm RDI. Both find no significant positive impacts of technology imports on firm RDI. However, the empirical results of this study have not provided any further evidence to support the studies conducted by Liu and Buck (2007) and by Wu (2008), which suggest that technology imports have a positive effect on either firms' innovation performance or on productivity growth.

The results, as shown in Estimation 1 and Tobit 1, indicate that the signs of the coefficients associated with total exports (TOLEXP) are both negative, –.105e-2 and –2.10e-2 respectively, although neither is at a significant level. These results suggest that, at an overall level, product exports do not have a positive impact on firm RDI. Furthermore, the negative sign that emerged in Tobit 1 suggests that there might be a negative effect (see Zhang, 2008). However, it does not provide evidence to support Zhao and Li (1997) and Liu and Buck (2007). Zhang (2008) suggests a complementary effect of product exports on firm RDI, while Zhao and Li (1997) and Liu and Buck (2007) indicate that product exports could promote high technology firms' innovation performance.

Next to be considered is the impact of the specific type of technology import and product export on firm RDI. First to be examined is the effect of disembodied technology imports on firm RDI. Empirical results in Estimation 2 and Tobit 2 show that the coefficients associated with IMPDIS emerge both as positive signs at 0.227 and 0.243 respectively, and at significant levels ($p<0.10$). This result might indicate that the disembodied technology imports have a significant positive effect on firm RDI. Second, in terms of the impact of embodied technology imports on firm RDI, the coefficient associated with IMPEM in Estimation 2 is –0.245e-2, but is 0.172e-3 in Tobit 2. Although they emerge as different signs, with one being positive and the other negative, neither of them is at a significant level. It is concluded therefore that the imports of embodied technology, which differ from those of disembodied technology, do not have a positive effect on firm RDI. Moreover, since Estimation 2 has a negative sign, it could be that embodied technology has a negative impact on firm RDI.

Kumar and Aggarwal (2005) find that disembodied technology imports do not have a positive impact on firm R&D intensity while, in contrast, the embodied technology imports do have a positive effect. This difference between the empirical results might be attributable to dissimilarities in absorptive capacity between firms in China and in India. Developed countries might prefer to export their advanced technologies in the form of machinery and plant, where the knowledge is embodied and incorporated, in order to maintain the confidentiality of their technologies. It might be, therefore, that embodied technology imports contain advanced technological knowledge, but knowledge that requires a high level of absorptive capacity if firms are to learn and make technological progress. As the statistics above suggest, India might have reached this high level of absorptive capacity by investing in capacity building. Therefore, it is the embodied technology imports in India that have the positive impact on firm RDI.

Next to be examined is the impact of high technology and non-high technology product exports on firm RDI. From Table 3 it can be seen that the coefficients associated with EXPHIT in Estimation 2 and Tobit 2 are positive at 0.073e-1 and 0.087e-1 respectively. Moreover, both are at a significant level ($p<0.10$; $p<0.05$). This result suggests that firms exporting high technology-related products are likely to be able to access advanced technologies and information from foreign countries. As these firms are exposed to intensified international competition, they are likely to increase R&D effort, hence the significant positive impact on their RDI. In contrast, it can be seen from both Estimation 2 and Tobit 2 that the coefficients associated with EXPTR emerge as negative signs (–0.014 and –0.021), with both at significant levels ($p<1\%$). This result is in line with the prediction that non-high technology product exports do not have a positive impact on firm RDI.

One interpretation of this result is that, with growing global trade liberalisation and economic integration, it is the multinational enterprise in developed countries that dominates the global value chain. Many developing countries are at the lower end of this value chain because of the competitive advantage they gain from lower costs; for example, through cheaper labour. It is unlikely that non-high technology product exports would stimulate firms' innovation capacity in these developing countries (Grossman and Helpman, 1991; Zhang, 2008). It is also of interest to examine the control variables' influences on firm RDI. From all estimations, it could be concluded that the technology purchased from the domestic market is positively associated with firm RDI at a significant level. One interpretation of this result is that the majority of technology domestically purchased is disembodied and so absorbed relatively easily. It could also be argued that the technologies generated from domestic R&D might be more appropriate for the application and development of these domestic firms because of their homogeneity. Therefore, firms that purchase this sort of technology domestically might stimulate their RDI.

The coefficients associated with PROFIT in the four estimations all emerge as positive signs and at significant levels; while those associated with DEBT all emerge as positive signs, but not at significant levels. These results suggest that the positive impact of firm liability on RDI is absent; however, as long as firms can generate profits and can provide investment when needed, they can increase R&D activities. In addition, the coefficient of CAPII shows a positive sign and at a significant level, suggesting that the greater the firm's capital intensity, the more efforts the firm is likely to make in RDI. In contrast, the coefficient associated with SIZE emerges as a negative sign, suggesting that the larger the firm, the less likely it is to increase investment in R&D. If it is assumed that firms with higher levels of capital intensity rely heavily on technology capacity as their competitive advantage, then these firms are more likely to have the capital to invest in R&D. However, large firms with major market share and considerable scale economies might have little incentive to invest in R&D. Additionally, the coefficient associated with HUMAN emerges as a significant positive sign, suggesting a firm with a higher level of human capital is more likely to invest further in R&D, which supports the observations and understanding in this study. Finally, it was found that the RDI in 3*Zis* and privately-owned firms are greater than those of state-owned firms.

Conclusions

RDI, exports and technology imports are considered to be the most important channels of international technology spill-overs and knowledge transfer. In particular, they provide firms in the developing nations with the opportunity to develop innovative capabilities and experience and to catch up with advanced world technology. Since economic reform in China in the late 1970s, RDI, exports and technology imports have witnessed significant growth. However, existing studies focus upon the impact of RDI on economic growth and technology development in China. Little research analyses the importance of product exports and technology imports and, in particular, their relation to firm RDI. Furthermore, few have explored this relation by separating the dissimilar characteristics of technology imports and product exports types.

This study used 1111 firms in the high technology sector in the Zhejiang province of China, with data covering 2003, 2004 and 2005. The appropriate estimation approach was considered carefully and empirically tested, proposing hypotheses from two perspectives: technology imports and product exports. Specifically, the analysis focused on the examination of the impact on firm RDI of both disembodied and embodied technology imports, as well as both high technology and non-high technology product exports. Overall, the analysis suggests that technology imports and product exports at an aggregated level do not have a positive impact on firm RDI. However, by further examining the relationships and separating the different types of technology imports and product exports, it was found that the disembodied technology imports have a significant positive impact on firm RDI, while the impact of embodied technology imports was absent and also suggested a possible negative impact. The high technology product exports have a positive impact on firm RDI while the non-high technology product exports have a significant negative impact on firm RDI.

The research presents significant policy implications for the Chinese government. First, since disembodied technology imports are easier for firms to absorb, they have a greater impact on improving their innovation capacities. For this reason, the Chinese government might consider encouraging imports of such disembodied technologies. The acquisition of intellectual property rights might promote these firms' innovation capacities. However, it would be a waste of money and less effective to import advanced machinery and other capital goods if such technology does not encourage firm RDI. It is therefore recommended that the Chinese government should be more cautious in encouraging imports of the embodied technology. Monitoring systems should be established to prevent firms from falling into the import lagged – import again trap, which creates little advancement in technology capability. The government could play an active role in this process by encouraging alliances among firms, universities and R&D institutions to engage in reverse engineering.

Second, the empirical results suggest that the government should re-evaluate its export policy and consider enhancing its support to those product exports with core technologies and intellectual property rights. In the meantime, support could be gradually reduced for non-high technology product exports; for example, by providing a tax refund to encourage firms to change their economic structure from traditional manufacturing to high technology. By encouraging firms to become involved in international competition and to generate knowledge from international spillovers, R&D and innovation will be promoted. Finally, it is important for firms to step up from the lower end of the global value chain. Only by competing with high technology products globally and by being exposed to intense competition can China promote its indigenous innovations effectively.

Notes

1. The statistics of technology imports in 1980 are drawn from Jin *et al*. (2008); the statistics of technology imports come from the Department of Service Trade, Ministry of Commerce (2008); the statistics of product exports come from the National Bureau of Statistics Commission and SSB (2008).
2. 3Zis – The following three types of enterprise are categorised as 3*Zis*. (*Zi* means capitals): foreign direct invested enterprises, foreign joint ventures and Sino-foreign collaborative enterprises.
3. The sales volumes for the non-responses in 2005 were obtained from DSTZJ, which reported the sales volumes of all 1718 firms.
4. In this study, consideration of the impact of industrial sectors on firm R&D investment was excluded. There are two reasons. First, the distribution of firms across the sectors is quite unbalanced, with only a small number of firms in some sectors. For example, there are only 22 firms in the New Energy sector, while there are 532 firms in the Electronic Machinery and Equipment sector. Second, all firms surveyed are in a high technology sector, which suggests a high level of homogeneity.

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