Differences in the impact of R&D intensity and R&D internationalization on firm performance – Mediating role of innovation performance

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Abstract

This paper investigates the mediating role of innovation performance in the effects of R&D intensity and R&D internationalization on firm performance, using 1,540 firm-year observations from a balanced panel of 385 privately-owned firms listed on the Shanghai and Shenzhen stock exchanges. Results show a negative effect of R&D intensity on short-term (profitability) and positive effect on long-term (firm value) financial performance but no significant effect on export (sales) performance. In contrast, R&D internationalization has a positive effect on export performance but no significant effect on short- or long-term financial performance. Moreover, innovation performance (number of patents) partially mediates the impact of R&D intensity and R&D internationalization on firm performance and these effects vary based on firm age and size. Besides extending current literature on R&D investments, these results have useful implications for firms especially those from emerging markets with international R&D operations or those aiming to internationalize their R&D activities.

Keywords: China; export performance; firm value; profitability; R&D intensity; R&D internationalization

1. Introduction

The impact of R&D investments on firm performance has attracted academic researchers for more than five decades with a general consensus that R&D investments have a positive effect on a firm's ability to innovate that in turn leads to greater productivity (e.g., Mansfield, 1962; 1980; 1986; Griliches, 1986). Numerous studies also show positive effects of R&D investments on the firms' innovation performance, represented by their level of patenting activity across a wide range of firms and industries, including new drug discovery (Jensen, 1987) and patents across pharmaceutical (Cardinal & Hatfield, 2000), chemical (Ahuja & Katila, 2001), computer (Hagedoorn & Duysters, 2002) and other industries (Peeters & de la Potterie, 2006). Hence, it is not surprising to see the global R&D investment reach a record high of US$1.7 trillion, with the top ten countries spending 3.3% of their GDP on R&D (UIS, 2020). In fact, as part of United Nation's Sustainable Development Goals (SDGs), public and private R&D investment is expected to continue to further increase in near future.

Overall, the positive link between the R&D investments and innovation performance (i.e., development of new products and services is quite well established, wherein firms investing in R&D are expected to be more likely to successfully develop and launch new products and technologies (Artz *et al*., 2010). Others show evidence of a positive relationship between R&D investments and financial performance, such as above-average profits (return on assets) in pharmaceutical industry (Roberts, 1999), initial public offer (IPO) valuation of biotech firms (DeCarolis & Deeds, 1999), firm growth and profitability of Fortune 1000 firms (Cho & Pucik, 2005), and overall financial performance in general (Hua & Wemmerlov, 2006).

Similar results are reported over the years around the world, for new technology ventures in China (Li & Atuahene-Gima, 2001), SME firms in Greece (Salavou, 2002), Japanese pharmaceutical firms (Penner-Hahn & Shaver, 2005), manufacturing and service firms in

Australia (Prajogo, 2006), newly listed firms in the UK, Germany, Italy and France (Filatotchev & Piesse, 2009), information technology and electronic firms in Taiwan (Yeh *et al*., 2010), and springboard subsidiaries of Chinese multinationals (Su *et al*., 2020). Thus, it is clear that firms use their R&D investments to improve their innovation performance by developing and launching a steady stream of new and innovative products and services to achieve high returns in terms of greater market share and superior financial performance.

Notwithstanding their useful contribution in highlighting the importance of R&D, most of these studies focus on either in-house or onshore R&D facilities and their influence on the firms' domestic performance (Priem, Li, & Carr, 2012), despite growing evidence that multinational firms need diverse international technological knowledge to improve the performance of their international expansion efforts (Brouthers, Brouthers, & Werner, 2001; Petruzzelli, Albino, & Carbonara, 2007; Vrontis & Christofi, 2019; Zahra, Ireland, & Hitt, 2000). In fact, recent changes in the social, economic and technological environment triggered by globalization have also accelerated the firms' efforts to look beyond their own knowledge management capacity to exploit and explore external R&D collaborations to improve their innovation performance (Deng, Delios, & Peng, 2020; Su *et al.*, 2020).

Firms are using external knowledge acquisition (Berchicci, 2013; Nieto & Rodriguez, 2012) and R&D offshore outsourcing (Martinez-Noya, Garcia-Canal, & Guillen, 2013; Weigelt & Sarkar, 2011) to improve their innovation performance (Su *et al*., 2020), as well as foreign direct investment in international R&D facilities to improve their competitiveness and efficiency through knowledge collaboration (Belderbos, Lokshin, & Sadowski, 2015; Papanastassiou, Pearce, & Zanfei, 2019; Su, 2017a, b). In fact, R&D internationalization is now an integral part of a global business strategy, as cross-border flow of capital, ideas, information, people, services, and technology creates a more efficient interdependent knowledge network (Bohnstedt, Schwarz, & Suedekum, 2012; Della Peruta, Campanella, &

Del Giudice, 2014; Galati & Bigliardi, 2019; Hsu, Lien, & Chen, 2015; Ritala *et al.*, 2018).

R&D internationalization is also increasingly being accepted as an important strategy (Di Minin & Bianchi, 2011; Di Minin, Zhang, & Gammeltoft, 2012). For example, emerging economies (e.g., China and India) are now using cross-border networks and offshore R&D facilities to target global markets, especially in the knowledge intensive industries (Binz & Truffer, 2017; Kollmann *et al.*, 2016), resulting in growing research interest on this topic. For example, a recent study shows that higher level of internal and external embeddedness of MNC subsidiaries shows multiplicative and positive effects on the degree of knowledge transfer (Ferraris, Santoro, & Scuotto, 2018). Others show that the presence of international R&D teams mediates the effect of R&D intensity on the knowledge creation process and new product performance (Adomako *et al.*, 2019). R&D internationalization also allows domestic and foreign firms to create knowledge complementarity by gaining vital knowledge from each other (Un & Rodríguez, 2018) and the impact of R&D internationalization on their innovative performance may be moderated by international collaboration (Hurtado-Torres, Aragón-Correa, & Ortiz-de-Mandojana, 2018). However, despite such growing research on the impact of R&D internationalization on various aspects of firm performance, there is no clear evidence about the differences in its impact vis-à-vis traditional R&D investments on firm performance (Chen & Hsu, 2010; Coluccia *et al.*, 2019; Tang, Tang, & Su, 2019).

As a result, the effect of R&D internationalization on financial and export performance remains unclear (Su *et al.*, 2020; Vithessonthi & Racela, 2016), especially in comparison to the impact of R&D intensity on firm performance (Altomonte *et al.*, 2016; Filipescu *et al.*, 2013; Lefebvre, Lefebvre, & Bourgault, 1998; Ossorio, 2018). In addition, the role played by innovation performance (e.g., number of patents) in the process by which R&D intensity and R&D internationalization influence firm performance is also not clear. These research gaps are major concerns for export-oriented firms, especially those from the emerging markets, as they aim to join global innovation networks to use international R&D efforts as a tool to improve their performance (Filatotchev *et al.*, 2009; Tang *et al.*, 2019).

We address the above research gaps in this paper. Specifically, we explore the differences in the impact of R&D intensity (R&D expenses to total sales) and R&D internationalization (presence of overseas research centers and foreign research staff) on firms' short-term (revenue growth and net assets per share) and long-term (Total Q and Tobin's Q) financial performance as well as their export performance (export sales and export intensity) while controlling for several variables, including industry type, level of patenting activity, board size, leverage etc. We hypothesize that R&D intensity has positive effects on long-term financial performance and export performance but negative effect on short-term financial performance. Next, we posit that R&D internationalization has positive effects on both short- and long-term financial performance but it is weaker than the effect of R&D intensity. Finally, we hypothesize that the firms' innovation performance (number of patents) would mediate the effects of R&D intensity and R&D internationalization on firm performance.

Using 1,540 firm-year observations from a balanced panel of 385 privately-owned Chinese firms in patent-intensive industries, listed on the Shanghai and Shenzhen stock exchanges, we find support for most of our hypotheses. Specifically, R&D intensity has a negative effect on short-term financial performance (profitability) and a positive effect on long-term financial performance (firm value) but no significant effect on export performance. In contrast, R&D internationalization has a positive effect on export performance but no significant effect on short- or long-term financial performance. Moreover, innovation performance (number of patents) partially mediates the impact of both R&D intensity and R&D internationalization on firm performance and these effects vary based on firm age and size. We discuss all these findings with their theoretical contribution and managerial implications along with some limitations of our research and directions for future research.

2. Theoretical background and hypotheses development

2.1. Traditional view of R&D investments

Past research for more than five decades shows that R&D investments help firms develop new and innovative products, processes, services and technologies, which in turn lead to greater productivity (e.g., Mansfield, 1962; 1980; 1986; Griliches, 1986) and superior financial performance, including above-average profits (Roberts, 1999), higher IPO valuations (DeCarolis & Deeds, 1999), higher profitability (Cho & Pucik, 2005), and overall financial performance (Hua & Wemmerlov, 2006). More recent studies provide deeper insights into the impact of R&D investments on firm performance by exploring the impact of R&D on its interface with sales and marketing functions (Homburg *et al.*, 2017), investor sentiment and marketing expenditure (Mian, Sharma, & Gul, 2018) as well as product and brand portfolio strategies (Kirca *et al.*, 2020), among others.

Most of these studies are based on the Cobb–Douglas production function that combines R&D as an input of the production function just like other resources, such as capital and manpower (Hall & Oriani, 2006). In addition, there is a general consensus on the role of R&D investments as a predictor of firm's market value or market capitalization. Thus, R&D investments are viewed as an important means by which firms can deliver innovative solutions to their customers and firms may use their R&D expenditure as a form of voluntary non-financial disclosure to the markets (Coluccia *et al.*, 2019). R&D investment also leads to long-term benefits for the firms as it allows companies to convert their R&D practices and strategies into profitable products and services, which result in greater revenues, profitability and market value (Falk, 2012). Overall, R&D productivity and efficiency positively affect firm value because analysts tend to favorably assess firms that use their R&D investment strategically to manage their innovation process and its outcomes (e.g., Lev & Gu, 2016;

Vithessonthi & Racela, 2016). However, firms need to utilize their R&D expenditure to create new products and services, as reflected in their innovation performance, in order to capitalize its benefits in terms of long-term financial performance. Hence, we hypothesize:

H1a. Innovation performance mediates the positive effect of R&D intensity on long-term financial performance.

The traditional view of the firm that a firm's sole purpose being increasing profits for its owners runs the risks of being focused on short-term gains and undue risk taking (Friedman, 1970; 2007). In contrast, stakeholder theory posits that a firm has to meet longer term and broader expectations of a diverse set of stakeholders and not just its shareholders, including any entity that can influence or be influenced by the actions of a business (Freeman, 1984). We argue that these contrasting views would also drive the traditional perceptions about the short-term versus long-term impact of R&D investment, such that firms may use R&D investments to generate long-term shareholder value at the expense of short-term profitability. The impact of R&D investment on short-term earnings is also uncertain due to a lack of predictability of financial measures (Gu & Li, 2003) and it may even be negative due to the 'immediate expensing' of R&D investment (Lev & Zarowin, 1999; Zéghal & Maaloul, 2011) or show a threshold effect in the form of an inverted U-shaped correlation between R&D intensity and firm performance (Yeh *et al*., 2010), suggesting a negative long-term effect.

More recently, Lev and Gu (2016) show that US high-technology firms with high R&D investments report high losses in their financial statements despite having increased their market capitalization over the last decade, thus their innovation performance seems to come at a huge cost. Similarly, Vithessonthi and Racela (2016) show that R&D intensity is negatively associated with operating performance and positively with firm value because investing in R&D infrastructure to develop new knowledge and capabilities may benefit a firm in the long run but it could have a negative effect on the short-term performance due to high initial investments. Coluccia *et al.* (2019) also argue that the impact of R&D activities on short-term financial performance may be negative due to the time-lag between R&D investments and their outcomes. We argue that one reason for these mixed effects could be that most of these studies ignore the important role of firms' innovation performance (i.e., the results of their R&D efforts) in the process by which their R&D investments may influence firm performance. Specifically, while R&D intensity may lead to innovation performance in the short run, this in turn could lead to a poor short-term financial performance due to huge upfront costs that R&D efforts may involve. Therefore, we hypothesize as follows:

H1b. Innovation performance mediates the negative effect of R&D intensity on short-term financial performance.

Early research shows that R&D investments are critical to the growth of exports and many empirical studies find a positive relationship between R&D investment and export performance (e.g., Audretsch & Yamawaki, 1988; Deardorff, 1984; Ito & Pucik, 1993). However, some studies raise doubts about this relationship (e.g., Schlegelmilch & Crook, 1988). In this context, Brouwer and Kleinknecht (1993) contend that the relationship between R&D investment and export performance may depend upon other variables, such as firm size, product category, nature of innovation etc. Moreover, the direction of causality in this relationship is still not clear; wherein, while it is assumed mostly that R&D investment has a positive impact on export performance, it may also be possible that successful exports may result in greater R&D investments. As most R&D expenditures tend to be fixed costs (e.g., equipment, labs, manpower), when firms expand their presence to export market, it would reduce their unit costs of R&D, which may in turn lead to greater R&D investments. In this context, we once again argue that the firm's innovation performance, such as the number of patents or new products suitable for international markets, may be the missing link between their R&D investments and export performance. In other words, firms would need to translate their R&D investments into innovative products and service suitable for their international markets in order to improve their exports performance. Accordingly, we posit as follows:

H1c. Innovation performance mediates the positive effect of R&D intensity on export performance.

2.2. Internationalization imperative of R&D investments

For the last couple of decades, multinational firms have been expanding their R&D facilities and infrastructure beyond their home countries in order to enhance their knowledge about the diverse characteristics of their international customers and markets, which in turn is expected to help them expand their international operations (Penner-Hahn & Shaver, 2005; Su *et al*., 2020; Zahra *et al.*, 2000). These efforts for internationalization of R&D operations and innovation processes by either acquiring external knowledge (Berchicci, 2013; Nieto & Rodriguez, 2012) or outsourcing their R&D activities (Martinez-Noya *et al.*, 2013; Weigelt & Sarkar, 2011). Many multinational firms also use foreign direct investment to expand their international R&D efforts with an aim to improve their performance in an increasingly globalized and highly competitive environment through knowledge collaboration and partnerships (Parida, Wincent, & Oghazi, 2016; Su, 2017a, b; Su *et al*., 2020). Past research also shows that multinational enterprises leverage their ability to acquire knowledge from a wide range of local, regional and global networks but it may depend on the strategic choice made by the headquarters about the role of their international R&D operations, level of scientific development of the host country, and the institutional distance between the home and host countries (Athreye, Batsakis, & Singh, 2016).

Early research into international R&D expansion activities used data on the research capabilities and patent output of 65 Japanese pharmaceutical firms from 1980 to 1991 to show that firms with existing research capabilities in the area of their knowledge (e.g., underlying or complementary technologies) were more likely to be able to gain advantage from their international R&D investments (Penner-Hahn & Shaver, 2005). Penner-Hahn and Shaver (2005) use asset-based theories of foreign direct investment and absorptive capacity to explain the motivation for R&D internationalization and the contingent nature of the benefits that the firms may draw from this process. Similar results are reported by others showing that R&D intensity is a key driver of growth in international sales but it depends on the levels of accumulated intangible assets and debt (Filatotchev & Piesse, 2009). Thus, it seems that R&D internationalization may not be enough to improve firm's long-term financial performance and we need a strong R&D intensity to achieve the best possible outcomes. In other words, R&D internationalization is expected to have a positive effect on long-term financial performance but it is likely to be weaker than the effect of R&D intensity. Moreover, these R&D internationalization efforts need to be focused on improving the firm's innovation performance in order to leverage their full potential. Accordingly, we hypothesize:

H2a. Innovation performance mediates the positive effect of R&D internationalization on long-term financial performance, which is weaker than the effect of R&D intensity.

Past research on the impact of internationalization and resource allocation on firm performance uses the resource-based view to highlight the importance of optimal resource allocation and utilization in driving the growth in a firm's international business (Chen & Hsu, 2010). In other words, appropriate deployment of international R&D resources may help firms improve their innovation performance by developing suitable products and services to quickly tap into the opportunities available in their international markets, which would enhance their short-term performance. In addition, Hsu *et al*. (2015) highlight firms with experience in international markets may be able to use it to strengthen the relationship between R&D internationalization and innovation performance. Hence, firms can use their experience of R&D internationalization to manage the complexity and uncertainty posed by their international markets and convert it into a positive short-term financial performance by improving their innovation performance, in the form of more patents and new products for international markets. Hence, we hypothesize as follows:

H2b. Innovation performance mediates the positive effect of R&D internationalization on short-term financial performance, which is weaker than the effect of R&D intensity.

With greater cross-national knowledge collaboration and R&D internationalization, multinational firms are able to create a more efficient and highly interdependent knowledge network, as a key part of their global business strategy (Bohnstedt *et al.*, 2012; Hsu *et al.*, 2015). Specifically, firms with past experience in international markets may be more capable to manage the complexities and uncertainties involved in international business, which may help them leverage R&D internationalization more effectively to achieve superior innovation and overall business performance (Hsu *et al.*, 2015). However, despite such growing popularity of R&D internationalization as an important element of firms' globalization strategy, there is no clear evidence about its impact on firms' domestic and international performance (Coluccia *et al.*, 2019). This is especially important for the export-oriented firms from the emerging markets as they aspire to expand their international R&D footprint and improve their export performance by internationalization of their R&D efforts (Filatotchev *et al.*, 2009; Tang *et al.*, 2019; Zhao *et al.*, 2020). In this context, recent studies show that R&D internationalization allows domestic and foreign firms to create knowledge complementarity by gaining vital knowledge from each other (Un & Rodríguez, 2018). Similarly, presence of international R&D teams mediates the effect of R&D intensity on the knowledge creation process and new product performance (Adomako *et al.*, 2019). Therefore, we expect R&D internationalization to have a stronger impact on firms' export performance due to its greater focus on the exports markets than R&D intensity, which focuses on both domestic markets. Moreover, as argued earlier, we expect the firms' innovation performance to mediate the impact of R&D internationalization on export performance because they need innovative products and services to tap their international markets. Accordingly, we hypothesize:

H2c. Innovation performance mediates the positive effect of R&D internationalization on export performance, which is stronger than the effect of R&D intensity.

Figure 1 summarizes our conceptual model with all the above hypotheses.

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3. Methodology

3.1. Sample

Our sample includes privately-owned firms listed on the Shanghai and Shenzhen stock exchanges from 2010 to 2013. Among the 1,493 privately-owned firms, we select those firms which are in patent-intensive industries[1] and provide financial statement information for the four years over 2010-2013. Our final sample includes a balanced panel of 385 firms with 1,540 firm-year observations. We extract data (financial statement information and board characteristics) from China Stock Market and Accounting Research (CSMAR) database. China provides an ideal research setting for this study because it is not only ranked 2nd in GDP in the world but it has also successfully transformed from a “copycat” to an innovative nation in the past ten years and is on the way to become a global “superpower” in innovation (World Economic Forum, 2018). Being one of the largest spenders on R&D, China improves its position from 43rd (the lowest rank) in 2010 to 17th (the highest rank) in 2018 according to the Global Innovation Index. The seeds for this unprecedented economic growth and focus on R&D was triggered by the speech made by ex-President Hu at the 17th National Congress in 2007, in which he declared one of China’s national objectives was the need to boost and

[1] Of the 45 industry sectors in China, we computed the average number of patents for each industry sector. We then ranked the mean number of patents from the highest to the lowest. The industry sector with the mean number of patents equal and greater than the industry median is considered to be patent-intensive industry.

relabel the image of 'Chinese brand name' in the global market. According to him, 'Chinese brand name' should be associated with 'designed in China' or 'created in China' besides with 'made in China', thus highlighting the importance of innovation and R&D for China's future.

3.2. Measures

We use two measures of export performance, including *Export Value*, the dollar value of export sales in logarithm form that signals the level of exports (Czinkota & Johnston, 1983); and, *Export Intensity*, the ratio of export to total sales value (Dominguez & Sequeira, 1993). We also use two indicators of short-term financial performance, including *Revenue growth,* which represents the growth in firms' revenues from the average of past three years to t+1; and, *Net Assets per Share*, the ratio of net assets to total number of outstanding shares, which represents asset value of a firm per share. We also use two measures for long-term financial performance, including *Tobin's Q,* the ratio of market value to book value of tangible assets (Bebchuck, Cremers, & Peyer, 2011); and, *Total Q*, the ratio of market value to book value of both tangible and intangible assets (Du & Osmonbekov, 2020). We use *Total Q* in addition to *Tobin's Q* because it accounts for the firms' intangible capital and captures the firms' investment opportunities better than other Tobin's Q proxies (Du & Osmonbekov, 2020).

We have two key independent variables, namely *R&D Intensity,* ratio of R&D investment to total sales (Adomako *et al.*, 2019; Vithessonthi & Racela, 2016; Yeh *et al.*, 2010) and, *R&D Internationalization*, a binary variable coded 1 when the firm has research centers overseas and/or foreigners in their research teams and 0 otherwise, as recommended by Un and Rodríguez (2018) who use a bivariate variable for R&D collaboration, and Penner-Hahn and Shaver (2005) who employ a dummy variable for international R&D activity. Next, we measured our mediator, innovation performance, as *Number of Patents,* which is the number of granted patents for inventions held by the firm in logarithm form.

We also include many control variables that may influence our results. For example, we include *Free Trade Zone,* a binary variable coded 1 if the firm is located in a free trade zone and 0 otherwise. A free trade zone is a designated geographical area where products can be imported, exported, and re-exported under special or fewer customs regulations and/or subject to lower or no customs duty. Hence, we expect that being located in a free trade zone may benefit firms' financial and export performance. China has 19 areas designated as free trade zone, including 14 coastal development zones in Beihai, Dalian, Fuzhou, Guangzhou, Lianyungang, Nantong, Ningbo, Qingdao, Qinhuangdao, Shanghai, Tianjin, Wenzhou, Yantai, and Zhanjiang, with five special economic zones in Shantou, Shenzhen, Xiamen, Zhuhai, and Hainan Island. We also include *Marketing Intensity,* the ratio of expenditure on marketing activity to total sales, used to measure marketing effort.

Next, we include a number of firm and board characteristics as control variables as these may also affect the firm's financial and export performance. For example, larger firms are more likely to export as compared to smaller firms (Christensen, Da Rocha, & Gertner, 1987) and there is a 'U-shaped' relationship between R&D productivity and firm size (Tsai & Wang, 2005). We use three indicators (*Board Size*, *Proportion of Independent Directors*, and *Proportion of Female Directors*) to control for the impacts of board characteristics and diversity on innovation (e.g., Midavaine, Dolfsma, & Aalbers, 2016). *Board Size* is the number of directors on board in logarithm form. Board independence is measured by *Proportion of Independent Directors*, ratio of independent directors to total number of directors on board. Board gender diversity is measured by *Proportion of Female Directors* (ratio of female directors to total number of directors on board).

Finally, we use four measures (*Firm Size*, *Firm Age, ROA*, and *Leverage*) to control for firm-specific characteristics. *Firm Size* is the dollar value of total assets in logarithm form. *Firm Size Dummy* is a binary variable coded 1 when a firm's value of total assets is below the industry median of total assets and 0 otherwise. Das (1994) finds firm age is negatively related to export performance, implying that young firms outperform more mature firms in export activity. Hence, we include *Firm Age*, the number of years the firm has been in operation in logarithm form. *Firm Age Dummy* is a binary variable coded 1 when a firm's age is below the industry median of firm age and 0 otherwise. *ROA* is return on assets (ratio of income to total assets). *Leverage* is the ratio of total liabilities to total assets that helps measure firm risk. To control for the industry effects during the four-year period, we include industry dummies in the models. Appendix 1 summarizes all these definitions.

3.3. Models

As all our hypotheses include mediating effects, we use the well-established method recommended by Baron and Kenny (1986) using three sets of regression models as shown below (Equations 1-3). The first model regresses all the independent variables including their interactions and the three performance outcomes as the dependent variables. Next, we regress the independent variables and their interactions on the mediator (innovation performance) as the dependent variable. Finally, we regress the independent variables as well as the mediator on the three performance outcomes as dependent variables. We analyzed the results from these three models to test for the mediating effects as explained in the next section.

$$\textit{Firm Performance} = b_0 + b_1 \textit{ R\&D Intensity} + b_2 \textit{ R\&D International} + b_3 \textit{ R\&D Intensity}^{*}\textit{Firm Size Dummy} + b_4 \textit{ R\&D Intensity}^{*}\textit{Firm Age Dummy} + b_5 \textit{ R\&D International}^{*}\textit{Firm Size Dummy} + b_6 \textit{ R\&D International}^{*}\textit{Firm Size Dummy} + b_i \textit{ Control Variables} + \varepsilon \qquad (1)$$

$$\textit{Innovation Performance} = b_0 + b_1 \textit{ R\&D Intensity} + b_2 \textit{ R\&D International} + b_3 \textit{ R\&D Intensity}^{*}\textit{Firm Size Dummy} + b_4 \textit{ R\&D Intensity}^{*}\textit{Firm Age Dummy} + b_5 \textit{ R\&D International}^{*}\textit{Firm Size Dummy} + b_6 \textit{ R\&D International}^{*}\textit{Firm Size Dummy} + b_i \textit{ Control}$$

Variables + ε (2)

Firm Performance = b_0 + b_1 *R&D Intensity*+ b_2 *R&D International* + b_3 *R&D Intensity***Firm Size Dummy* + b_4 *R&D Intensity***Firm Age Dummy* + b_5 *R&D International***Firm Size Dummy* + b_6 *R&D International***Firm Size Dummy* + b_6 *Number of Patents* + b_i *Control Variables* + ε (3)

4. Data analysis and findings

We use balanced panel data in a firm random effects model with industry and year fixed effects, containing 1540 observations from 385 firms over a four years period (2010-2013). We employ firm random effects model because it helps control for firm-level heterogeneity when analyzing panel and cross-sectional time series data, which includes the fixed effects of time trend during the sample period across different industry groups (Kim, Kim, & Lee, 2021). We also include year fixed effects to control for unobservable year effects and temporal shocks, and industry fixed effects to capture the effect of unobservable industry-specific characteristics. Including more fixed effects in our model helps us mitigate the effects of unobservable variables and omitted variable bias (Chen, 2004; Kim *et al*., 2021). In addition, we use "lagging independent variable" approach to address endogeneity problem that may exist due to simultaneity and reversed causality (Zaefarian, Kadile, Henneberg, & Leischnig, 2017). Specifically, we employ the lagged endogenous regressor technique to investigate the direction of causality in the time-series lead-lag relationship between the endogenous variables to create a temporal separation between the independent and dependent variables that helps reduce the possibility of reversed causality (Zarfarian *et al*., 2017).

Table 1 reports the descriptive statistics (mean and standard deviation) and correlations of all the variables used in this study. We identified only 126 (32.73%) firms in our sample with R&D internationalization. Hence, we used univariate test to compare the characteristics between subsamples of firms with and without R&D internationalization (Table 2). We found significant differences in export performance between the two subsamples ($p < .01$) wherein the firms with R&D internationalization have higher export sales value as well as higher export intensity. These firms also have larger net assets per share, number of patents, firm size, and leverage but are less likely to be located in free trade zone (Table 2).

< Insert Tables 1 and 2 about here >

Table 3A and 3B present the results of our multiple regression analysis. First, as shown in Table 3A, _R&D Intensity_ has significant positive effects on _Revenue Growth_ and _Tobin's Q_ but a negative effect on _Net Assets per Share._ In contrast, _R&D International_ has significant positive effects on both _Export Value_ and _Export Intensity_. Among other variables, _R&D Intensity*Firm Size Dummy_ has a significant positive effect on _Total Q_, _R&D Intensity*Firm Age Dummy_ has a significant negative effect on _Revenue Growth_ and _R&D International*Firm Age Dummy_ has a significant positive effect on _Revenue Growth_. _Firm Size Dummy_ also has negative effects on _Export Value_ and _Net Assets per Share_ and positive effects on both _Tobin's Q_ and _Total Q_. _Firm Age Dummy_ only has a positive effect on _Net Assets per Share_. _Free Trade Zone_ has a positive effect on _Export Intensity_ and _Marketing intensity_ has negative effects on export and short-term financial performance indicators but positive effect on long-term firm performance indicators. All the other control variables have mixed effects on all the outcome variables, hence these are not discussed in detail. The tolerance levels of the VIF (variance inflation factor) values are all non-significant, indicating no multicollinearity problem in our data.

< Insert Tables 3A and 3B about here >

Next, first column of Table 3B shows significant positive effects of _R&D International_ and _R&D Intensity*Firm Size Dummy_ (but not _R&D Intensity_) on _Number of Patents_. Among other variables, *Firm Age Dummy* has a negative effect and *Leverage* has a positive effect on *Number of Patents*. Finally, the remaining columns of Table 3B show that the positive effects of *R&D Intensity* on both *Revenue Growth* and *Tobin's Q* and negative effect on *Net Assets per Share*. The positive effects of *R&D International* on both *Export Value* and *Export Intensity* remain significant in the presence of *Number of Patents*. Hence, innovation performance (measured as *Number of Patents*) seems to partially mediate the influence of *R&D Intensity* on both short- and long-term financial performance as well as the influence of *R&D International* on export performance, showing partial support for H1a, H1b, and H2c. Moreover, unlike *R&D Intensity*, *R&D International* has no significant effects on short- and long-term financial performance, which supports H2a and H2b. Finally, *R&D Intensity* has no significant effect on export performance, hence H1c is not supported. Therefore, we find partial or full support for all our hypotheses except one (H1c).

Among the other variables, *R&D Intensity*Firm Size Dummy* has significant positive effects on both innovation performance and long-term financial performance. Hence, the positive effects of *R&D Intensity* seem to be stronger for larger firms. In contrast, *R&D Intensity*Firm Age Dummy* has a positive effect on innovation performance but a negative effect on *Revenue Growth*, hence it seems that smaller firms may be more innovative but they may not be able to translate this into short-term financial performance, represented by revenue growth. In contrast, *R&D International*Firm Age Dummy* has no significant effect on innovation performance but has a positive effect on *Revenue Growth*, which suggests that older firms with greater international R&D presence may not be able to produce more innovative outcomes but they may be able to leverage their market presence to generate greater revenue growth. *Number of Patents* also has positive effects on both exports and short-term financial performance, which lends further support to the above findings. None of the control variables have any clear effects on all the outcome variables.

5. Discussion

In this paper, we study the mediating role of innovation performance (e.g., number of patents) in the impact of R&D intensity (R&D expense to total sales) and R&D internationalization (presence of overseas research centers and foreign research staff), on firm performance, including short- (profitability) and long-term (firm value) financial performance, and international (export) performance. We used 1,540 firm-year observations from a balanced panel of 385 privately-owned Chinese firms in patent-intensive industries, listed on the Shanghai and Shenzhen stock exchanges, to test and find support for most of our hypotheses. Specifically, R&D intensity has a negative effect on short-term financial performance (profitability) and a positive effect on long-term financial performance (firm value) but no significant effect on export performance. In contrast, R&D internationalization has a positive effect on export performance but no significant effect on short- or long-term financial performance. Finally, innovation performance (number of patents) partially mediates the impact of both R&D intensity and R&D internationalization on firm performance and these effects vary based on firm age and size. In addition, some control variables also have significant effects on the three firm performance measures. In this section, we discuss the theoretical contribution and managerial implications of these findings.

5.1. Theoretical contribution

With recent growth in the internationalization of R&D by many multinational firms, it is being recognized as a vital component of their overall global business strategy, and yet, despite its growing importance, there is hardly any research comparing the differences in the impact of R&D intensity and R&D internationalization on firm performance (Coluccia *et al.*, 2019; Deng *et al.*, 2020; Tang *et al.*, 2019). Moreover, with most studies exploring the impact of firms' R&D investments on their domestic and export performance (e.g., Altomonte *et al.*, 2016; Filipescu *et al.*, 2013; Lefebvre *et al.*, 1998; Ossorio, 2018), there is paucity of research on the impact of R&D internationalization on financial and export performance (Su, 2017a, b; Su *et al*., 2020; Vithessonthi & Racela, 2016). Finally, despite considerable evidence about the impact of R&D intensity and R&D internationalization on innovation performance, its role in the process by which R&D investments influence firm performance is still not clear.

We address these important research gaps by comparing the impact of R&D intensity and R&D internationalization on the firm's short-term and long-term financial performance and export performance, and exploring the mediating role of innovation outcome (number of patents) in this process. Besides extending the growing literature on R&D internationalization and its impact, we also contribute to the current research on the factors that drive the performance of export-oriented firms from the emerging markets. Specifically, we use China as our research setting to show the importance of R&D internationalization as a strategic tool for the success of multinational companies from the emerging markets in the international markets (Filatotchev *et al.*, 2009; Tang *et al.*, 2019; Zhao *et al.*, 2020).

Recent studies explain the impact of R&D internationalization on firm performance by showing that it allows firms from different parts of the world to fill gaps in each other's knowledge by developing knowledge complementarity (Un & Rodríguez, 2018). Moreover, multinational firms also use their international R&D teams to strengthen the impact of their R&D efforts and investments on their knowledge creation process, which in turn improves the performance of their new products and services (Adomako *et al.*, 2019). Coluccia *et al.* (2019) extend this line of research by introducing a new firm-level measure for innovation activities, namely R&D elasticity, and exploring its effects on the value of firms listed on the Euronext 100 Index. They find evidence of a positive association between R&D elasticity and market appreciation by stakeholder investors in terms of firm value (Tobin's Q).

Our findings extend these results by exploring the differences in the effects of traditional measures of R&D effectiveness (e.g., R&D intensity) and R&D internationalization to show that R&D intensity has a negative effect on short-term (profitability) and positive effect on long-term (firm value) financial performance but no significant effect on export (sales) performance. In contrast, R&D internationalization has a positive effect on export performance but no significant effect on short- or long-term financial performance. Moreover, innovation performance (number of patents) partially mediates the impact of R&D intensity and R&D internationalization on firm performance and these effects vary based on firm age and size. All these are important new findings that would pave the way for more research on the impact of R&D internationalization on firm performance.

In this context, Belderbos *et al.* (2015) explore the individual and combined impact of foreign and domestic R&D investments on firm performance using a large panel of firms in Netherlands. They show that for firms in industries in which the home country lags behind the global players, foreign R&D complements domestic R&D investments and provides positive returns; and by contrast, for firms in industries that match the global players, domestic R&D has a stronger impact on productivity. Belderbos *et al.* (2015) use a knowledge stock augmented production function framework to explain these effects in terms of productivity convergence and declining returns on R&D. We extend these findings by showing that R&D intensity, which primarily consists of domestic R&D investments, has no significant effect on export performance, has a negative effect on short-term financial performance, and has a positive effect only on long-term financial performance. In contrast, R&D internationalization has significant positive effects on not only export performance but also both short- and long-term financial performance. Moreover, innovation performance plays a pivotal mediating role in the process by which both these measures of R&D investments influence firm performance. Thus, our study provides many meaningful insights over and above those provided in extant research (e.g., Belderbos *et al.*, 2015).

We also find some useful insights about the differences in these effects among the firms based on their age and size. For example, we find that the positive impact of R&D intensity on both innovation performance and long-term financial performance is stronger for larger firms, which makes sense because it is quite plausible that larger firms may be in a better position to leverage their R&D investments to deliver more innovative products and services, which in turn would lead to better financial performance. Interestingly, the positive effect of R&D intensity is stronger for smaller firms on innovation performance but weaker on their short-term financial performance (revenue growth), which may reflect their lack of resources and capabilities to translate their innovative outcomes into superior financial performance.

In contrast, we find significant differences based on firm age in the positive impact of R&D internationalization on revenue growth but not on innovation performance, which suggests that older firms with stronger international R&D presence may be able to leverage their superior market presence and experience to produce greater revenue growth even with a lower level of innovative outcomes compared to their younger counterparts. Finally, we also confirm that the firms' innovation performance (e.g., number of patents) has positive effects on both exports and short-term financial performance, although its impact on the long-term financial performance (i.e., firm value) is not as clear. All these findings provide useful new insights and help us extend the current literature on R&D internationalization.

5.2. Managerial implications

Companies from the emerging markets (e.g., China and India) have been investing in international R&D (e.g., in Europe) with three different objectives, a) explore and exploit technological opportunities, b) capitalize on locational advantages, and c) leverage the unique resources offered by overseas R&D units (Di Minin *et al.*, 2012). For example, Chinese firms such as ZTE Corporation, JAC Motors, Chang'an Motors, and Hisense Group have initially set up R&D activities in Europe mostly driven by motivation to learn from the experts there rather than seeking technological innovation. However, their strategies seem to have evolved over a period of time from a pure exploration of technology to a mix of foreign technologies with their own, and more recently, to exploit new technologies available in foreign locations. Our results show that one of the motivations for this shift in the strategy by multinationals from emerging markets could be the positive impact of R&D internationalization on firms' financial and export performance, mediated by innovation performance (e.g., number of patents). Thus, emerging market firms may use our results to justify the internationalization of their R&D activities through global research and knowledge partnerships.

A recent study of R&D investment since 1980 shows an interesting growth pattern across different countries around the world (Dehmer *et al.*, 2019). For example, the United States started from a fairly large base of R&D investment in 1980 ($149.5 million) but its growth has been overtaken by other countries, resulting in a drop in its share of global domestic R&D investment from 31.2% in 1980 to 27.4% in 2013. Similarly, R&D investment by 15 former Soviet states has fallen to just over half of their 1980 levels in 2013, after adjusting for inflation. These declines are in stark contrast to the tremendous jump in R&D investment by Asian countries like China, South Korea, and India; China's global share has jumped from 1.2% in 1980 to 19.2% in 2013 making it the 2nd biggest R&D spender in the world. South Korea has shot up from 36th rank to become the world's 5th highest R&D spender, while India's R&D investment has grown by 6.7% per year on average, helping it rise to 7th position with Brazil's ranking among top 10 R&D spenders.

These increases in R&D investment in the emerging markets have led to huge improvements in their R&D infrastructure, including highly qualified and well-trained scientists and world-class infrastructure, which the firms from the developed markets are now trying to exploit in order to internationalize their R&D operations (Dehmer *et al.*, 2019). Others have identified several challenges and risks for the firms from the developed markets in diversifying R&D activities to the emerging markets, including a lack of understanding about the local consumers and ability to develop products and services to meet their diverse needs, cultural and linguistic differences coupled with unique local business practices, and concerns about intellectual property rights (Brem & Wolfram, 2017). Our findings indicate that firms from both developed and emerging markets would need to manage their R&D internationalization efforts in view of their significant impact on their performance.

6. Limitations and future research

Our study has a few limitations that future research could address. First, we use data for Chinese firms in patent-intensive industries, hence future research could use data from other emerging markets to test the generalizability of our results. Moreover, it would be useful to examine the impact of R&D internationalization efforts by firms from the developed markets to expand their R&D operations in the emerging markets, such as China and India. Second, we test the direct effects of R&D intensity and R&D internationalization on firms' financial and export performance. Hence, future research could test their interactive effects with each other and other relevant variables such as marketing intensity. Finally, future research could operationalize the variables in our conceptual model using different indicators to those used by us, to test the robustness of our measures and to possibly further extend our model.

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Figure 1. Conceptual model

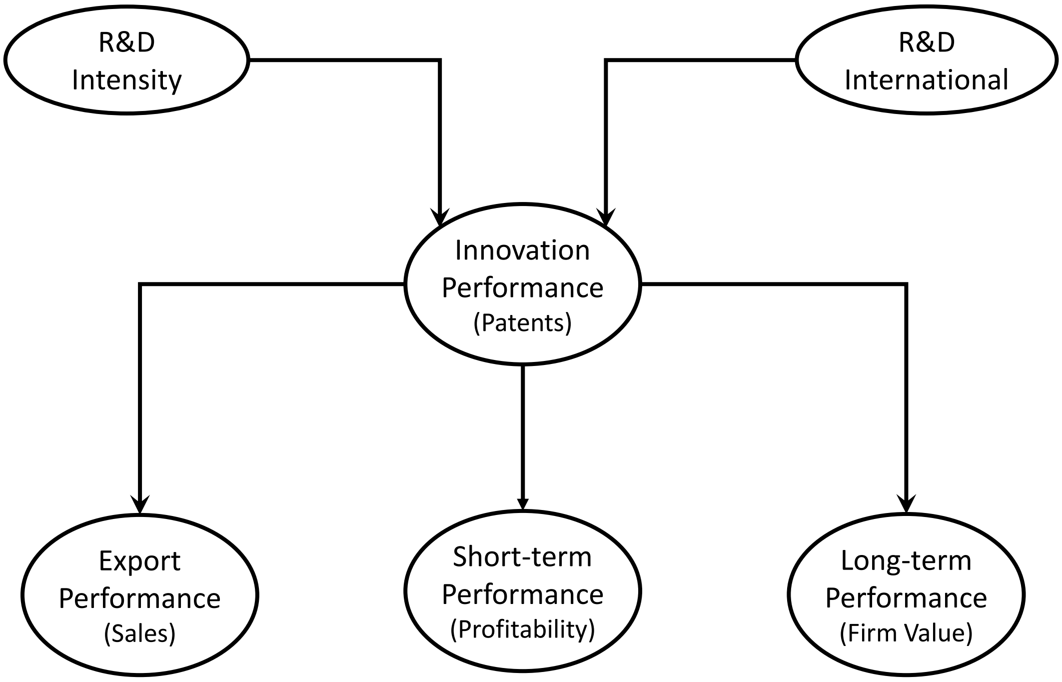

Table 1. Descriptive statistics and correlations

	Variables	*Mean*	*SD*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	*R&D Intensity*	0.01	0.02	1							
2	*R&D International*	0.33	0.47	0.01	1						
3	*Number of Patents*	1.33	1.21	0.04	0.11**	1					
4	*Firm Size Dummy*	0.5	0.5	0.08**	-0.14**	-0.22**	1				
5	*Firm Age Dummy*	0.51	0.5	0.03	-0.04	-0.07**	0.19**	1			
6	*Free Trade Zone*	0.35	0.48	-0.08**	-0.08**	0.02	0.09**	0.14**	1		
7	*Marketing Intensity*	0.07	0.05	0.18**	0	0.06*	0.13**	-0.01	0	1	
8	*Board Size*	2.22	0.21	-0.05*	0.05	0.19**	-0.20**	-0.06*	-0.04	-0.02	1
9	*Proportion of Independent Directors*	0.38	0.07	0.03	-0.04	0.04	0.02	0	0.07**	0.07**	-0.08**
10	*Proportion of Female Directors*	0.14	0.12	-0.03	-0.02	-0.03	0.09**	0.04	0.01	0.03	-0.07**
11	*Return on Assets*	0.05	0.05	-0.04	-0.02	-0.01	-0.02	0.05	0.03	-0.08**	-0.06*
12	*Leverage*	0.35	0.19	-0.17**	0.08**	0.12**	-0.42**	-0.28**	-0.10**	-0.18**	0.16**
13	*Export Value* at time t+1	14.04	8.29	-0.05	0.13**	0.27**	-0.15**	0.06*	0.05	-0.12**	0.08**
14	*Export Intensity* at time t+1	0.18	0.23	-0.06**	0.07**	0.09**	-0.01	0.08**	0.13**	-0.18**	0.03
15	*Revenue Growth* at time t+1	1.32	0.58	0.05	0.05*	0.02	-0.02	0.06**	0.06*	-0.02	-0.10**
16	*Net Assets per Share* at time t+1	4.5	2.28	-0.03	0.06**	-0.02	-0.04	0.12**	0.01	0.02	-0.07**
17	*Total Q* at time t+1	7.13	6.45	0.19**	-0.02	-0.07**	0.22**	0.04	0.10**	0.20**	-0.10**
18	*Tobin's Q* at time t+1	2.23	1.13	0.24**	-0.03	-0.02	0.26**	0.06*	0.06*	0.19**	-0.07**

* $p < .05$, ** $p < .01$

….continued on next page

	Variables	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*
1	*R&D Intensity*										
2	*R&D International*										
3	*Number of Patents*										
4	*Firm Size Dummy*										
5	*Firm Age Dummy*										
6	*Free Trade Zone*										
7	*Marketing Intensity*										
8	*Board Size*										
9	*Proportion of Independent Directors*	1									
10	*Proportion of Female Directors*	0.07**	1								
11	*Return on Assets*	-0.02	0.02	1							
12	*Leverage*	-0.03	-0.13**	-0.28**	1						
13	*Export Value* at time t+1	0.03	0.03	-0.04	0.07**	1					
14	*Export Intensity* at time t+1	0.07**	0.03	0.00	-0.05	0.56**	1				
15	*Revenue Growth* at time t+1	0.00	-0.07**	0.14**	0.04	0.01	0.05*	1			
16	*Net Assets per Share* at time t+1	-0.03	0.02	0.18**	-0.30**	0.09**	0.02	0.10**	1		
17	*Total Q* at time t+1	0.09**	0.07**	0.14**	-0.29**	-0.12**	-0.03*	0.05*	-0.05*	1	
18	*Tobin's Q* at time t+1	0.13**	0.05*	0.14**	-0.23**	-0.10**	0.04	0.21**	-0.20**	0.63**	1

* $p < .05$, ** $p < .01$

Table 2. Sample comparison (Mean values)

	R&D Internationalization		
	Yes	No	Difference
R&D Intensity	0.01	0.01	0.00
Number of Patents at time t+1	1.82	1.49	0.33**
Firm Size	21.55	21.29	0.26**
Firm Age	2.25	2.21	0.04
Free Trade Zone	0.29	0.37	-0.08**
Marketing Intensity	0.07	0.07	0.00
Board Size	2.23	2.21	0.02†
Proportion of Independent Directors	0.38	0.38	-0.01†
Proportion of Female Directors	0.13	0.14	-0.01
ROA	0.04	0.05	0.00
Leverage	0.37	0.34	0.03**
Export Value at time t+1	15.55	13.30	2.25**
Export Intensity at time t+1	0.20	0.17	0.04**
Revenue Growth at time t+1	1.36	1.30	0.06*
Net Assets Per Share at time t+1	4.71	4.40	0.31*
Total Q at time t+1	6.96	7.21	-0.25
Tobin's Q at time t+1	2.18	2.25	-0.07
Number of Observation	504	1036	

†p < .10, * p < .05, ** p < .01

Table 3A. Multiple regression analysis output (All dependent variables at time t+1)

Independent variables at time t	**Export Performance**		**Short-term Financial Performance**		**Long-term Financial Performance**	
	Export Value	Export Intensity	Revenue Growth	Net Assets per Share	Total Q	Tobin's Q
Intercept	13.63^{**}	0.24^{**}	1.73^{**}	6.21^{**}	7.45^{**}	2.37^{**}
R&D Intensity	-7.80	-0.06	3.36^{**}	$-6.76^{\dagger}$	-19.77	4.60^{*}
R&D International	1.81^{*}	0.05^{*}	-0.02	0.30	-0.14	-0.11
*R&D Intensity**Firm Size Dummy*	-0.32	0.46	2.01	3.64	40.06^{**}	1.69
*R&D Intensity**Firm Age Dummy*	-5.63	-0.24	-3.90^{**}	-5.20	-0.60	$3.63^{\dagger}$
*R&D International**Firm Size Dummy*	1.06	0.02	-0.04	0.17	-0.03	0.06
*R&D International**Firm Age Dummy*	0.04	-0.02	0.24^{**}	-0.07	0.61	0.18
Number of Patents	NA	NA	NA	NA	NA	NA
Firm Size Dummy	-1.23^{*}	0.00	0.01	-0.46^{**}	1.30^{**}	0.37^{**}
Firm Age Dummy	0.09	0.00	0.03	0.31^{*}	-0.33	-0.05
Free Trade Zone	0.98	0.06^{**}	0.05	-0.03	0.72	0.06
Marketing Intensity	$-9.51^{\dagger}$	-0.29^{*}	-0.28	$-2.52^{\dagger}$	$7.76^{\dagger}$	$1.24^{\dagger}$
Board Size	0.63	-0.02	-0.26^{**}	-0.26	-0.50	-0.26^{*}
Proportion of Independent Directors	-0.45	0.03	-0.06	-0.86	2.46	0.75^{*}
Proportion of Female Directors	1.20	0.06	$-0.28^{\dagger}$	$0.93^{\dagger}$	1.20	-0.14
ROA	-2.02	-0.07	1.38^{**}	-0.82	6.97^{*}	1.68^{**}
Leverage	0.12	-0.05	0.42^{**}	-2.44^{**}	-5.01^{**}	-0.27
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-square	0.09	0.03	0.06	0.12	0.12	0.19
F Statistic	5.96	2.57	4.19	7.58	7.51	12.50
p-value	0.00	0.00	0.00	0.00	0.00	0.00
Number of Observations	1540	1540	1540	1540	1540	1540

$^{\dagger}p < .10$, $^{*}p < .05$, $^{**}p < .01$

Table 3B. Multiple regression analysis output (All dependent variables at time t+1)

	Innovation Performance	Export Performance		Short-term Financial Performance		Long-term Financial Performance	
Independent variables at time t	Number of Patents	Export Value	Export Intensity	Revenue Growth	Net Assets per Share	Total Q	Tobin’s Q
Intercept	1.12**	12.89**	0.23**	1.73**	6.24**	7.63**	2.38**
R&D Intensity	-1.29	-4.76	-0.04	3.50**	-6.84†	-20.44	4.57*
R&D International	0.31*	1.57†	0.04†	-0.03	0.31	-0.06	-0.11
*R&D Intensity*Firm Size Dummy*	3.25**	-5.91	0.39	1.85	3.84	41.58**	1.76
*R&D Intensity*Firm Age Dummy*	2.02†	-8.59	-0.25	-4.06**	-5.13	0.45	3.68†
*R&D International*Firm Size Dummy*	0.00	1.00	0.02	-0.05	0.17	-0.01	0.06
*R&D International*Firm Age Dummy*	-0.01	0.06	-0.02	0.25**	-0.07	0.59	0.18
Number of Patents	NA	1.09**	0.02**	0.03*	-0.04	-0.33†	-0.01
Firm Size Dummy	-0.01	-1.03†	0.00	0.02	-0.47**	1.22**	0.37**
Firm Age Dummy	-0.09*	0.20	0.00	0.03	0.31*	-0.35	-0.05
Free Trade Zone	0.11	0.86	0.06*	0.04	-0.02	0.76	0.06
Marketing Intensity	0.76	-10.93*	-0.30*	-0.32	-2.49†	8.25*	1.26†
Board Size	0.04	0.43	-0.02	-0.28**	-0.25	-0.43	-0.26*
Proportion of Independent Directors	0.16	-0.42	0.02	-0.06	-0.86	2.46	0.75*
Proportion of Female Directors	0.12	1.28	0.06	-0.27†	0.93†	1.18	-0.14
ROA	0.14	-2.65	-0.07	1.33**	-0.81	7.26*	1.70**
Leverage	0.52**	-0.46	-0.06	0.40**	-2.40**	-4.85**	-0.26
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-square	0.44	0.11	0.04	0.06	0.12	0.12	0.19
F Statistic	38.21	6.60	2.74	4.16	7.36	7.41	12.13
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Number of Observations	1540	1540	1540	1540	1540	1540	1540

$^{\dagger}p < .10$, $^{*}p < .05$, $^{**}p < .01$

Appendix I. Operationalization of variables

Variable	Definition
R&D Intensity	Ratio of expenditure on R&D to total sales
R&D Internationalization	Binary variable coded 1 when the firm has research centers overseas or foreigners in their research teams and 0 otherwise
Number of Patents	Number of granted patents for inventions held by the firm in logarithm form
Firm Size Dummy	Binary variable coded 1 when a firm's value of total assets is below the industry median of total assets and 0 otherwise
Firm Age Dummy	Binary variable coded 1 when a firm's age (the number of years firms have been established in logarithm form) is below the industry median of firm age and 0 otherwise
Free Trade Zone	Binary variable coded 1 if the firm is located in a free trade zone and 0 otherwise
Marketing Intensity	Ratio of expenditure on marketing activity to total sales
Board Size	Number of directors on board in logarithm form
Proportion of Independent Directors	Ratio of independent directors to total number of directors
Proportion of Female Directors	Ratio of female directors to total number of directors on board
ROA	Return on total assets, which is the ratio of income to total assets
Leverage	Ratio of total liabilities to total assets
Export Value	Dollar value of export sales in logarithm form
Export Intensity	Ratio of export sales value to total sales value
Revenue Growth	Ratio of sales at t+1 to average sales of time t, t-1 and t-2
Net Assets per Share	Ratio of net assets to total number of outstanding shares
Total Q	Ratio of market value of assets to book value of total (tangible and intangible) assets (Du & Osmonbekov, 2020)
Tobin's Q	Ratio of market value of assets to book value of tangible assets (Bebchuck *et al.*, 2011)