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Does Export Trade Promote Firm Innovation?

Yueling Cai, Gongliang Wu, and Dingsheng Zhang*

With globalization, exports as a leading means for firms to operate internationally can not only help firms expand their market and gain economies of scale, but also provide opportunity to gain international experience and technological know-how. Using data of Chinese industrial firms and customs data from 2001 to 2007, this study empirically tests the impact of export trade on innovation. The results show that firms' participation in exports can significantly increase the likelihood of product innovation. Moreover, this study further verifies the impact mechanism and finds that the magnitude of the export learning effect is less than that of the market size effect. This study provides new ideas for China's trade transformation and upgrading, and has policy significance for guiding international operations of firms, maintaining a free international trading system, and stimulating firm exports.

Key Words: Firm export; Export learning effect; Market scale effect; Firm innovation.

JEL Classification Numbers: F31, F41, L25.

1. INTRODUCTION

Scholars have recognized the importance of exports in the global economy (Dhanaraj and Beamish, 2003). Export is one of the most common means of entering the international market (Azar and Ciabuschi, 2017). It enables firms to use idle operating capabilities and improve production efficiency, thereby increasing profits and ensuring survival in highly globalized markets (Matanda and Freeman, 2009). Firms that increase their exports may engage in more formal and informal interactions with local or international organizations (e.g., foreign organizations) (Belussi and Sedita, 2012; Gal-

* Cai: International Business School, University of International Business and Economics, Beijing, 100029, China. Yueling Cai acknowledges financial support from the National Social Science Foundation of China(18ZDA056); Wu: Corresponding author. China Economics and Management Academy, Central University of Finance and Economics, Beijing, 100081, China. Email: wugl1991@126.com; Zhang: China Economics and Management Academy, Central University of Finance and Economics, Beijing, 100081, China.

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breath, 2019). These interactions provide an opportunity to learn about the technical aspects or profitability of innovation in a particular organization (Gertler 2001). Having an open attitude to participate in export trade complements firms' internal capabilities and search strategies for external resources. The international market is viewed as a network of relationships, and firm entities are interconnected through multiple channels and models. In this context, the role of international competition (not the cost-based competition but the product design, performance, and customer service) is emphasized because it reshapes the strategic choices of a firm (Gkypali et al., 2018).

Regarding the impact of exports on innovation, many scholars hold the export promotion theory, that is, exports can promote innovation through scale, competition, spillover, and export learning effects (Seenaiah and Rath, 2018). Moreno-Menendez (2018) believe that export behavior and cooperative innovation affect each other through a co-evolution process, and export activities have a much greater impact on innovation. When faced with changing competitive pressure in the export market, firms show positive innovation behavior. Specifically, Dai et al. (2018) found that compared with non-export firms, the research and development (R&D) expenditure of export firms increased by 11% under such situations, with product development increasing by nearly 1.5 times. In particular, export activities can serve as an additional channel for firms' networking efforts, as foreign market access can provide opportunities to build relationships with various types of external knowledge partners to gather technical or market know-how (Tomiura, 2007).

However, some scholars also advocate the export suppression theory (Stokey, 1991). They believe that developing countries mainly use their comparative advantages on labor, resources, and the environment to enter global value chains dominated by multinational firms through processing trade, original equipment manufacturer (OEM), and other methods. Most of their exports are labor-intensive and have low added value. Therefore, such exports are easy to be captured by leading multinational firms, making the long-term "low-end lock-in" dilemma difficult to overcome, which is not conducive to innovation.

This study theoretically analyzes existing literature to infer the relationship between China's export trade and firm innovation, and establish corresponding hypotheses. We use microdata of Chinese industrial firms to study the relationship between firm exports and innovation and alleviate the endogenous problems that macro data may bring. Second, we further verify two channels through which an firm's export affects innovation — the export learning effect channel and the market scale expansion channel — and reached conclusions and inspirations based on the Chinese context. The marginal contribution of this study is that we verified the two chan-

nels through which export trade affects firm innovation, and found that the effect of market size channels on firm innovation is greater than the export learning effect. Specifically, with regard to the mechanism, firms reduce production costs by increasing the scale of investment in innovation. When foreign markets increase their demand for domestic products, they have two important effects on the innovation mechanism of domestic firms. First, the direct market size effect not only expands the export market, but also increases the rate of return on innovation and stimulates domestic export firms to increase investment in R&D. Second, with regard to the competitive effect, the enlarged market attracts new firms to enter the export market, thereby increasing the competition among export firms to enter foreign markets, and this competitive effect disappears with the increase of firm productivity.

2. THEORETICAL ANALYSIS

2.1. Literature review

This study mainly investigates whether export trade promotes firm innovation and its internal influence mechanism. The paper makes a marginal contribution to the literature of trade, growth, and innovation (Grossman and Helpman, 1991). Early studies on trade and growth innovation mainly focused on import trade (Bustos, 2011; Bloom et al., 2016), while subsequent studies considered export trade. Traditionally, the economic benefits of export trade have been considered to be based on factor endowment or the quality of products and services (Wheeler et al., 2008). The underlying positive link was from R&D innovation to exports. A large number of studies considered the impact of innovation on export at the national (macro), industry, and firm (micro) levels by including export flow, decision-making, and performance. The mechanisms involved included the self-selection effect, learning-by-exporting effect, and so on. By contrast, few studies have shown a reverse relationship (Ganotakis and Love, 2011), and this did not happen until the endogenous growth model realized the possibility of a reverse relationship from export to innovation (Grossman and Helpman, 1991). The knowledge creation process and export activities are interrelated (Love and Ganotakis, 2013), and engaging in R&D cooperation may have a positive impact on innovation performance (Antonelli and Colombelli, 2015) or a negative impact (Gkypali et al., 2017).

Trade policy also has a strong impact on the innovation behavior of export firms, but with a time lag. Buryi and Lahiri (2019) examined two policy instruments — a matching grant and import tariffs — for encouraging R&D in the product innovation of a domestic firm when faced with foreign competition. He found that in response to a reduction in import tariffs, the domestic firm always reduces its private R&D investments, but

the total level of R&D expenditure (i.e., including public support) might go up depending on the level of tariffs. In particular, it goes up if the initial level of tariff is higher than a critical level. When a tariff is endogenous, the socially optimal level of tariffs is positive. One finding that is of particular interest is that supporting private attempts toward product innovation in the form of a matching grant program leads to a socially optimal level of product R&D. Clerides et al. (1998) and Bernard and Andrew (1997) studied the positive impact of export on productivity. Lileeva and Trefler (2007) further concluded that free trade agreements promote the improvement of firm productivity, with the benefiting firm investing more in adopting new technologies and product innovation, thus proving the causal effect of export on productivity and innovation.

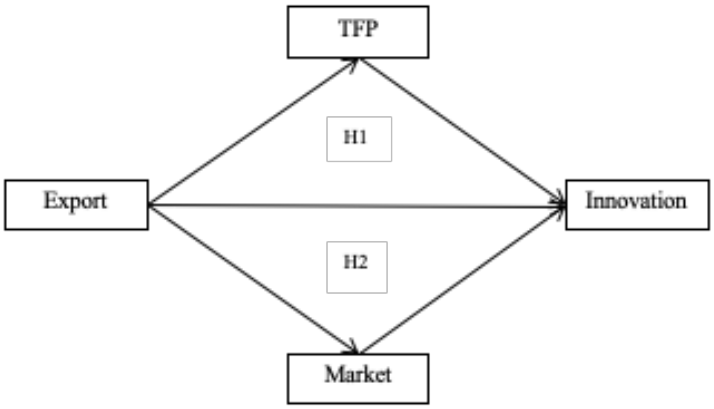
Some scholars have discussed the heterogeneity of the export trade impact on firm innovation. The export trade structure of different product types has different effects on innovation. A country that continuously exports labor-intensive products increases its labor cost and thus, increases the cost of innovation, thereby inhibiting firm innovation (Grossman and Helpman, 1991). Yang (2018) examined whether and how heterogeneity in exports affects firms' innovation. He found that exports, overall, have a positive impact on promoting innovations in terms of R&D and new product sales. The innovation-enhancing effect of exports depends on the heterogeneity in exports. Firms with greater varieties of exports, more market diversification, and higher export quality are associated with a higher propensity for R&D and more new product sales, while process exports are found to have a negative association with innovations. Feder (1983) divided export products into primary and manufactured products to find heterogeneity in the impact of different export product types on firm innovation. Damijan et al. (2017) investigated the relationship between firms' export status and different sorts of innovation activities. They found a systematically positive relationship between the two, whereby the strongest correlation is found in the case of product innovation and the weakest in the case of organizational innovations. While aggregate data show that innovation success increases as the firm's size increases, they found that exporting has the strongest effect on innovation for medium-sized firms. They also explored cross-country differences in the impact of export status on innovation and found that countries with a higher share of exports in gross domestic product (GDP) and a greater share of spending on R&D generally display stronger correlation between exporting status and innovation. Export intensity is positively associated with green innovations (Galbreath, 2019). Di Cintio et al. (2019) investigated whether the choice to directly export versus indirectly export plays a role in the innovation behavior of exporting firms. He found that firms that directly export have a higher probability of introducing product innovation compared to non-exporter

firms and indirect exporters. Fassio (2018) analyzed the effect of exporting activity on the innovative performances of firms in France, Germany, Italy, Spain, and the United Kingdom. He argued that the positive effect of exporting on innovation usually found in the literature varies according to the specific destinations of exports, and he identified two dimensions along which export destinations might differ: the level of foreign technological spillovers available to exporting firms (the technological learning effect) and the type of foreign demand that exporting firms are able to access (the foreign demand effect). The empirical analysis shows that while the technological learning effect increases mainly the incentives to introduce brand new product innovations, the foreign demand effect fosters the adoption of process innovations.

2.2. Hypothesis development

The literature review shows that export trade can positively affect the innovation behavior and results of firms. If so, how can exports promote firm innovation? To reveal the channels of its impact, the following conceptual model and the assumptions proposed in this study explain the impact of firm exports on innovation in terms of the export learning and market size effects (Fig. 1).

FIG. 1. Conceptual model



The export learning effect channel. The export learning effect emphasizes the absorption and transformation of knowledge and technology, and therefore focuses more on learning output activities such as innovation (Salomon and Shaver, 2005). Learning from external sources is a key means of obtaining valuable new ideas in the innovation process (Cruz-GonzáLez et al., 2015). Important technology spillover channels can promote the diffusion and transfer of foreign technology to the focal country (Greenaway

and Yu, 2004). Technological diversity in the international market provides learning opportunities for exporting firms. Exports enable firms to acquire knowledge about new products and processes more quickly, and exposure to the international market expands their access to new ideas, knowhow, and other important resources. From these resources, firms can draw the elements needed for the innovation process (Kylaheiko et al., 2011). Moreover, the competition in more demanding foreign markets forces them to continue to improve products and processes. Exporting firms can also observe and imitate the management experience and operating methods of foreign firms, and combine innovation with the firm's own products. In an open economy that is still far below the technological frontier, De Loecker (2013), and Rebelo and Silva (2017) have suggested the need to take action aimed at increasing absorptive capacity and technological improvements to promote innovation performance so that firms can move from simply entering export markets to gaining the benefits of learning.

According to the new trade theory, firms can at least increase productivity through the learning effect and knowledge spillover effect when exporting new products (Krugman, 2011). Since the pioneering work of Bernard, Jensen, and Lawrence (1995), more and more studies have confirmed that exporting companies are generally larger, with higher wages, and are more capital-intensive than non-exporting firms, and most importantly, have higher productivity (De Loecker, 2007; Dai et al., 2018). The productivity advantage of exporting firms can be attributed to the productivity gains achieved through exports. Crespi et al. (2008) found that firms exporting in the past were more inclined to learn from foreign customers and showed faster future productivity growth. Exporters that invest in R&D are the most productive firms in capital-intensive industries. Investment in R&D enables exporting firms to adapt and absorb foreign technologies, thereby increasing productivity (Criscuolo et al., 2010; Dai and Yu, 2013). In the case of developing countries, exporting firms can gain advanced technological knowledge through continuous exchange of information and business relations with foreign importers and competitors. This will enable them to improve their technology, gain trade spillovers, and increase business productivity (Greenaway and Kneller, 2007; Damijan and Kostevc, 2015).

Customers are an important source of external knowledge in the innovation process (Prahalad and Ramaswamy, 2004). Firms work closely with customers to respond to a rapidly changing environment and meet various challenges such as low cost, fast delivery, high quality, flexibility, and customer service requirements (Zhao et al., 2011). Firms use customers as a key source of innovation knowledge, to complement internal innovations, or as a source of unique inventions (Wang et al., 2016). Various empirical evidence support the relationship between customers and firm innovation performance, both positive impacts and negative or insignificant impacts

(Lau et al., 2010). Chang and Taylor (2016) suggested a moderate relationship between customer engagement and product innovation (Silva et al., 2019).

Meanwhile, because importers play a decisive role in international trade relations (Leonidou et al., 2011), they provide export firms with links to host country retailers (Yalcinkaya et al., 2007) and perform a number of functions that are critical to the smooth operation of the firm as a whole (Skarmeas and Robson, 2008). In the context of international commercial trade, importers are a key source of customer knowledge for firms pursuing product innovation. Due to the importer's control and knowledge of how to access local markets, export manufacturers are interested in engaging them in product development (Li and Lin, 2015). Importers also have vested interests in cooperating with exporting firms to develop products, as they have made significant investments in developing product markets and share similar risks. Moreover, both would benefit from convenient market access and better quality of exported products (Li and Lin, 2015). Exporting companies can continuously obtain feedback on the firm's competitive products from foreign agents and customers, as well as diversified information on consumer preferences about products, thereby enabling them to further adjust and improve their production process and achieve innovation (Bernard and Andrew, 1997; Crespi et al., 2006; Bratti and Felice, 2011).

Hypothesis 1. Exports promote firm innovation through export learning effects.

The market scale effect channel. The direct market size effect brought by enterprises' participation in exports refers to the expansion of the market size, the increase in innovation income, and the increase in R&D investment of domestic export enterprises (Atkeson and Burstein, 2018). Enterprises operating in the international market can reduce the risk of R&D investment by avoiding excessive changes in local market demand. Export activities not only represent international competition and firm competitiveness (Tsekouras and Skuras, 2005) but also enable firms to expand their knowledge base by expanding their market share. Krugman (1997), after analyzing the impact of global trade on R&D innovation from the demand side, highlighted the economies of scale brought about by firms' participation in exports and encouraged firms to carry out R&D innovation mechanisms. Export trade expands firms' original production scale and brings economies of scale (Djankov and Hoekman, 2000). Even if firms invest higher R&D costs to reduce marginal costs and increase productivity, they will achieve higher sales scale growth and higher profits under specific price demand elasticities. A more substantial return on innovation will motivate firms to innovate more. At the same time, the entry of firm products into overseas markets can increase firm brand awareness

and improve firm performance, thereby increasing the dynamics of firm innovation.

Firms participating in the international market have higher productivity and innovation tendencies (Castellani and Zanfei, 2007) because the competitive effect forces exporters to continuously improve inefficiencies in production, which disappears as the productivity of the firm increases (Melitz, 2003; Aghion et al., 2019). Technological innovation is seen by firms as a magic weapon for survival or for maintaining a certain level of profit under conditions of fierce competition (Aghion et al., 2005). Under fierce market competition, firms often need to improve production processes, upgrade machinery and equipment, and continuously innovate in terms of product style, quality, and design to increase sales and generate more profits, thereby addressing the competitive pressures of export trade (George et al., 2002). Meanwhile, along with the knowledge spillover effect, the gap in technology between developed and developing countries shrinks, as the spread of technology and competition in the international market intensifies. The resulting pressure will force firms to upgrade or maintain continuous innovation to remain internationally competitive and gain market share (Aghion et al., 2005). At the same time, the trade penetration and trade shocks of developing countries will force the current state of innovation toward a new round of technological innovation, thus forming a beneficial interaction between trade exports and technological innovation.

Hypothesis 2. Exports promote firm innovation through market size effects.

3. RESEARCH METHODOLOGY

3.1. Data collection

The data used in our study was derived from the China Industrial Firms Database and the matching database of the China Industrial Firms Database and the China Customs Database from 2001 to 2007. The industrial firm database is derived from the China Annual Survey of Industrial Firm (CASIF) conducted by the National Bureau of Statistics of China. The database comprises industrial firms with sales of more than 5 million yuan (more than 20 million yuan since 2011) in mainland China, including state-owned, collective, private, and other domestic-funded firms; Hong Kong, Macao, and Taiwan-invested firms; foreign-invested firms, and so on. According to Brandt et al. (2012), in 2004, these firms accounted for more than 90% of the total manufacturing output in China and over 71% of industrial employment. Statistical variables include the basic situation of the firm, its financial situation, and its production and sales. The statistics cover more than 40 large industries in China's industrial manufac-

turing sector, more than 90 medium-sized industries, and more than 600 sub-industries.

Data on firms' export trade come from the China Customs Database published by the General Administration of Customs. The matching database not only includes the firms' production, sales, and other financial information but also covers their export price, quantity, and scope. After a successful matching, we further process the samples as follows: (1) exclude outliers with missing or less than 0 core variables and samples with less than 15 employees in the firm and (2) exclude firm sample data that do not comply with accounting standards. The variable definitions and data sources are reported in Table 1 below and the descriptive statistics for each variable are reported in Table 2.

TABLE 1.

Definition, data source, and description of the main variables

Variables	Definition	Data source and description
Innovation	Firm innovation	Industrial firms database; calculated according to the logarithm of the new product output value
Export	Firm export	Industrial firms database; calculated based on the logarithm of the firm's export delivery value
Size	Firm size	Industrial firms database; the number of employees (logarithm)
Wage	Firm salary level	Industrial firms database; the total salaries of employees payable in the focal year divided by the total number of employees
Finance	Financing constraints	Industrial firm database; the ratio of interest expenditure to fixed assets
TFP	Productivity	Industrial firms database; total factor productivity calculated by the LP method
Market	Export market size	Payne table; denoted by the total GDP of the destination of a firm's exports
Profit	Firm profit	Industrial firms database; the difference between total profit and subsidy income, logarithmically calculated
Age	Firm age	Industrial firms database; focal year?year of establishment +1 (logarithm)

3.2. Variables

According to the previous theoretical analysis, firm innovation and firm export are the two core variables of this research. Firm innovation capability can be measured by the R&D investment and number of new patents granted by firms (Audretsch, 1996). However, firm R&D investment can only reflect the firm's investment in innovation but cannot measure the amount of innovation output of the firm. In addition, the number of new patents in firms has certain limitations in measuring the innovation output

TABLE 2.

Descriptive statistics of the main variables

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Innovation	1398177	0.7607	2.6099	0.0000	18.5159
Export	1665682	2.5028	4.2706	0.0000	19.0140
Market	1645585	17.6457	1.4387	8.0297	21.2961
Size	1656587	4.7293	1.1518	0.0000	12.1450
Wage	1635509	2.4581	0.6208	0.2548	10.6659
Finance	1614483	0.0376	0.0704	−0.0282	0.6057
TFP	1604510	6.9875	1.2566	−2.6200	14.9883
Profit	1614946	0.0221	0.0973	−0.7636	0.3377
Age	1607427	1.8649	0.9712	0.0000	7.6038

of firms, and it is impossible to accurately understand the value of firms' innovation output. Based on the above considerations, this study uses the output value of new products to describe the innovation ability of firms. The firm's export (*Export*) is used as an independent variable and is measured by the export intensity, which is measured by the total annual export value of the firm.

In terms of control variables, *Size* represents the size of the firm and is measured by the number of employees in the firm. *Wage* indicates the salary level of the firm, while *Profit* reflects the profitability of the firm and uses the difference between the total profit and the subsidy income of the firm to measure the average profit rate of the firm. *Age* indicates the age of the firm, which affects the strategic development and operation of the firm and possibly the innovation behavior of the firm as well. This study uses the difference between the focal year and the year of establishment of the firm to indicate the age of the firm.

3.3. Empirical model

According to the theoretical part of the analysis, the econometric model for constructing the influence of firm export on firm innovation is as follows:

$$\ln(\text{Innovation}_{it}) = \alpha + \beta \ln(1 + \text{Export}_{it}) + \gamma \text{control}_{it} + \delta_f + \delta_c + \delta_s + \delta_t + \varepsilon_{it} \tag{1}$$

where i and t represents the firm and time, respectively and the explained variable $\ln(\text{Innovation}_{it})$ represents the logarithm of the innovation output of firm i in year t. The explanatory variable Export_{it} indicates the export value of firm i in year t plus 1, and the logarithm is used to increase the sample size. For the robustness of the measurements, the model incorporates firm-level control variables to control for firm size and firm financing.

The degree of restraint, salary level, profit, and age of the firm and other factors affecting the innovation of the firm are included. Moreover, the model also includes the fixed effects of the firm δ_f, urban area δ_c, national economy 4-digit industry code δ_s, and year δ_t. ε_{it} represents a random error term.

4. EMPIRICAL RESULTS

4.1. Baseline estimates

First, the regression equations of the econometric model are estimated, and the fixed effects of the firm, year, region, and industry are controlled for. The results are shown in Table 3. Column (1) only controls for the fixed effect of the firm and the year; column (2) controls for the fixed effects of the firm, year, and industry; column (3) controls for the fixed effects of firms, years, and urban areas; and column (4) controls for the fixed effects of firms, years, industries, and regions. Results from columns (1) to (4) show that the participation of firms in export has a significant positive effect on the innovation ability of firms, and the coefficient estimates are relatively stable (ranging from 0.1249 to 0.1411). Thus, hypothesis 1 is verified. According to the results in column (4), when the other conditions are unchanged, the firm product export intensity increases by 1%, and the firm product innovation output value increases by 0.125%. There is a large amount of processing trade in China's export firms. The R&D level and productivity of processing trade firms are often low, which leads to the productivity of China's export firms not being significantly higher than that of non-export firms (Tianmin Min et al., 2013). With reference to Wang Yaqi and Lu Bing (2018), the model controls for the fixed effect of the firm, and the processing trade effect is thus absorbed by the fixed effect of the firm, eliminating the interference of the processing trade on the regression coefficient of the firm's exports.

With regard to the control variables, the regression coefficient of the size of the firm is significantly positive, which indicates that the larger the firm, the higher the value of the firm's new product output. The possible reason is that a large firm is more expensive than a small firm. The lesser a firm is subject to restrictions on R&D costs and technological levels, and the lesser it relies on the advantages of economies of scale for R&D innovation, the higher the output value of new products. Furthermore, the regression coefficient of firm financing constraints is positive. This study uses the ratio of interest expenditure to fixed assets to measure firm financing constraints. The greater the ratio, the more capable the firms are in obtaining loans from banks and other institutions, and the lesser the financing constraints. The regression results show that the lesser the degree of financing constraints, the more capable the firms are with regard to investing in R&D, which is

TABLE 3.

Benchmark regression

	(1) Innovation	(2) Innovation	(3) Innovation	(4) Innovation
Export	0.1411***	0.1409***	0.1251***	0.1249***
	(0.0015)	(0.0015)	(0.0018)	(0.0018)
Size	0.1935***	0.1916***	0.1995***	0.1984***
	(0.0060)	(0.0060)	(0.0073)	(0.0073)
Finance	0.3961***	0.3880***	0.2144***	0.2071***
	(0.0399)	(0.0399)	(0.0481)	(0.0481)
Wage	0.0516***	0.0526***	0.0459***	0.0465***
	(0.0053)	(0.0053)	(0.0064)	(0.0064)
Profit	0.0293	0.0261	0.1772***	0.1727***
	(0.0291)	(0.0291)	(0.0330)	(0.0330)
Age	−0.0255***	−0.0262***	−0.0400***	−0.0396***
	(0.0058)	(0.0059)	(0.0066)	(0.0066)
Cons	−0.6077***	−0.5989***	−0.5710***	−0.5668***
	(0.0356)	(0.0356)	(0.0433)	(0.0433)
Firm-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Region-fixed effects	No	No	Yes	Yes
Industry-fixed effects	No	Yes	No	Yes
N	1164435	1164431	869971	869966
R^2	0.705	0.706	0.730	0.731

Note: Standard errors are in parentheses; ***, **, and * indicate significance levels at 1%, 5%, and 10%.

conducive to the development of R&D innovation activities. The coefficient of firm wages indicates that higher wages can attract more talent for firms and help firms enhance their innovation ability through the accumulation of human capital, and thereby produce more new products. The profit margin is significantly positive. The higher the profitability, the more capable the firm is in product innovation. Meanwhile, the age of the firm is significantly negative. Products with longer operating lives often have an advantage in the market, and firms that do not have such products have greater motivation to develop new products or pursue product innovation.

The participation of firms in export has significantly improved the innovation capability of such firms in China. The main effects are as follows. First, considering the market scale expansion effect, the expansion of the market scale has increased the rate of innovation and encouraged domestic export firms to increase R&D investment. Second, considering the export learning effect, Chinese export firms gain international experience

and advanced technology through their exports, and obtain performance improvement (such as production efficiency or demand income), thereby enhancing their innovation ability. Considering the competitive incentive effect, when firms participate in export activities, competition in the international market becomes more intense, and firms start participating in innovation activities more actively to win the market.

4.2. Endogeneity

When discussing the impact of firm export behavior on innovation, it is also necessary to consider that firm innovation may have a reverse effect on firm export behavior — the stronger the firm's innovative R&D capabilities, the stronger and more competitive its products are in the international market and thus, the more favorable it is for the firm to export. The existence of the above two-way causal relationship inevitably leads to endogeneity problems, which leads to bias in the estimation results of the empirical model. To overcome the endogeneity problem as much as possible, we take the first-order difference for the econometric model (1) and choose the strategy of tool variables in the later lag period .The choice of instrumental variables needs to meet two conditions. One is not related to the interference term, and the other is highly correlated with the endogenous variable. The lag period of the firm is related to the current export, which affects the innovation ability of the firm by influencing the current value. However, the current innovation capability of the firm does not affect the export of the firm in the lagged period. Therefore, the firm export lag of the first phase I can be used as the instrumental variable of the sub item of current value, and the two-stage least squares method (2SLS) can be used to deal with the endogeneity problems that may exist. The regression results are shown in columns (3) and (4) of Table 4. At the same time, as a reference, columns (1) and (2) of Table 4 also report the OLS estimation results of the core variable lag phase I. The regression results of the instrumental variables show that the regression coefficient of the core explanatory variable (firm export) is still significantly positive at the 1% significance level. Compared with the benchmark regression results, the coefficient sign and saliency have not changed substantially, indicating that the model is well considered. After addressing the endogeneity problem, the regression results are still valid.

In addition, considering the rationality of the instrumental variables will directly affect the validity and consistency of the estimation results. Thus, the following statistical tests are performed on the instrumental variables in the 2SLS used in this study. (1) The Kleibergen-Paap rk LM statistics are 2112.05 and 2104.16, and the corresponding P values are 0.0000. The original hypothesis of the insufficient identification of tool variables is significantly rejected at the 1% significance level. (2) The weak instrument

TABLE 4.

Results after processing the endogeneity problem

Innovation	OLS estimation (the core variable lags in the first phase)		IV estimate(the core variable takes the first-order difference and lags in the first phase)	
	(1)	(2)	(3)	(4)
Export (lag 1)	0.05311***	0.0226***		
	(0.0059)	(0.0058)		
Export (D1)			0.2447***	0.2414***
			(0.0032)	(0.0034)
Year-fixed effects	Yes	Yes	Yes	Yes
Control variables	No	Yes	No	Yes
N	108633	102878	781840	692960
R^2	0.0026	0.0478	0.2131	0.2124
Kleibergen-Paap rk LM Statistic			2112.05***	2104.16***
Weak Instrument F Statistic			5835.67***	5053.48***

Note: Standard errors are in parentheses; ***, **, and * indicate significance levels at 1%, 5%, and 10%.

F-statistics are 5835.67 and 5053.48, and the corresponding P values are 0.0000. The null hypothesis of weak recognition is significantly rejected at the 1% significance level, indicating that the instrumental variables used in this study are valid. In short, after dealing with the endogeneity problem, the conclusion remains, that is, the participation of firms in exports is an important factor that affects the innovation of firms.

4.3. Heterogeneity test

Analysis by region. Considering China's vast territory and the significant differences between different regions, we divide China into eastern, central, and western regions to examine the heterogeneity of the impact of firm exports on firm innovation. The sample estimation results of different regions show that the promotion effect of firm exports on firm innovation in the central region is significantly greater than that in the eastern and western regions, and the promotion effect in the eastern region is the smallest. The eastern coastal region is where China's foreign trade firms are most concentrated in and was the earliest to open to the outside world. Compared with the central and western regions, its export has a relatively small role in stimulating firm innovation. Compared with the western region, the central region's geographical advantages and good and convenient infrastructure are conducive to foreign trade, and also have a significant role in promoting the firm's R&D and innovation capabilities.

TABLE 5.

Heterogeneity test 1 (analysis by region)

	Eastern region	Central region	Western region
Export	0.0643***	0.4376***	0.1084***
	(0.0015)	(0.0057)	(0.0079)
Size	0.2204***	0.1589***	0.3037***
	(0.0075)	(0.0183)	(0.0199)
Finance	0.3004***	−0.0381	0.1525
	(0.0373)	(0.1119)	(0.1347)
Wage	0.0423***	0.0291***	0.1258***
	(0.0066)	(0.0161)	(0.0171)
Profit	0.0939**	0.3815***	0.2422***
	(0.0375)	(0.0773)	(0.0535)
Age	0.0043	−0.1153***	0.0404***
	(0.0068)	(0.0139)	(0.0134)
Cons	−0.6811***	−0.1775	−1.1559***
	(0.0446)	(0.1088)	(0.1184)
Firm-fixed effects	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes
Region-fixed effects	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes
N	726,190	141296	117136
R^2	0.719	0.754	0.743

Note: Standard errors are in parentheses; ***, **, and * indicate significance levels at 1%, 5%, and 10%.

Analysis by industry level. Subdividing the overall level into 28 manufacturing industries, we explore the differential impact of firm exports on firm innovation in different industries. Among them, the textile and apparel industry, shoes and hats leather industry, furniture industry, printing industry, and so on are divided into low and medium technology industries, and the pharmaceutical manufacturing, rubber manufacturing, and communications equipment industries are divided into medium and high technology industries. We find that for both samples of low-tech and high-tech industries, firm exports have a significant role in promoting firm innovation. However, the impact of firm exports on firm innovation in low- and medium-tech industries is less than that in China's technology industries.

Analysis by the nature of different firms. Domestic foreign-funded firms in China are mostly export-oriented firms, and foreign-funded firms usually have greater export tendency and export value. Thus, considering that the nature of different firms may have different impacts on firm innova-

tion, we classify the firms as follows. Chinese-foreign joint ventures, wholly foreign-owned firms, and Chinese-foreign cooperative firms are classified as foreign-funded firms. State-owned firms, private firms, and collective firms are classified as non-foreign-funded firms.

TABLE 6.

Heterogeneity test 2 (analysis by industry level and business nature)

	Low-tech industries	High-tech industries	Foreign firms	Domestic firms
Export	0.1022***	0.1409***	0.0414***	0.0826***
	(0.0021)	(0.0029)	(0.0037)	(0.0071)
Size	0.1196**	0.4092***	0.1439***	0.6708***
	(0.0543)	(0.0809)	(0.0267)	(0.0574)
Finance	0.0036	0.0314***	0.3285	0.2652
	(0.0072)	(0.0112)	(0.2248)	(0.3474)
Wage	0.2370***	0.3756***	0.0354	0.1798***
	(0.0398)	(0.0590)	(0.0259)	(0.0581)
Profit	−0.0445***	−0.0010	0.0546	0.0732
	(0.0075)	(0.0110)	(0.1196)	(0.1071)
Age	0.2872***	0.7485***	−0.0485	−0.0324
	(0.0226)	(0.0362)	(0.0907)	(0.0830)
Cons	0.1022***	0.1409***	−0.3054	−2.5088***
	(0.0021)	(0.0029)	(0.2799)	(0.4382)
Firm-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Region-fixed effects	Yes	Yes	Yes	Yes
Industry-fixed effects	No	No	Yes	Yes
N	489982	386531	80291	39833
R^2	0.669	0.750	0.736	0.817

Note: Standard errors are in parentheses; ***, **, and * indicate significance levels at 1%, 5%, and 10%.

4.4. Robustness checks

Replacing the explained variable, which is the measure of firm innovation. In the previous analysis, new product output value was used to measure firm innovation. This time, it is measured by firm R&D expenditure, and the model regression equation is rerun. The results remain significant and stable.

Removing extreme values. After removing the extreme values of firm innovation and firm exports from the sample, that is, the smallest or largest 2% of the firm sample, the regression results remain robust.

TABLE 7.

Robustness test

Innovation	Replacement indicator	After removing extreme values
Export	0.0093^{***}	0.1194^{***}
	(0.0023)	(0.0017)
Size	0.3916^{***}	0.1440^{***}
	(0.0186)	(0.0067)
Finance	0.5082^{***}	0.1594^{**}
	(0.1199)	(0.0463)
Wage	0.1524^{***}	0.0279^{***}
	(0.0162)	(0.0060)
Profit	0.8228^{***}	0.1452^{***}
	(0.0644)	(0.0315)
Age	0.1163^{***}	-0.0302^{***}
	(0.0171)	(0.0064)
Cons	3.1889^{***}	0.3639^{***}
	(0.1222)	(0.0401)
Firm-fixed effects	Yes	Yes
Year-fixed effects	Yes	Yes
Region-fixed effects	Yes	Yes
Industry-fixed effects	Yes	Yes
N	16428	852058
R^2	0.835	0.764

Note: Standard errors are in parentheses; ***, **, and * indicate significance levels at 1%, 5%, and 10%.

5. MECHANISM

5.1. Mediation effect model

In the previous analysis, we verified the significant positive impact of firm exports on firm innovation. Next, we verify the channels through which firm exports affect firm innovation. According to the analysis of the theoretical mechanism, we choose firm productivity (TFP) and firm market size ($Market$) as mediator variables, and firm export (Export) as the core explanatory variable. The mediation effect model for testing the market size expansion effect and export learning effect is set as follows:

$$TFP_{it} = a_0 + a_1 \ln(1 + \text{Export}_{it}) + \gamma \text{control}_{it} + \delta_f + \delta c \delta s + \delta_t + \varepsilon_{it} \quad (2)$$

$$Market_{it} = b_0 + b_1 \ln(1 + \text{Export}_{it}) + \gamma \text{control}_{it} + \delta_f + \delta c \delta s + \delta_t + \varepsilon_{it} \quad (3)$$

$$\begin{aligned} innovation_{it} &= c_0 + c_1 \ln(1 + Export_{it}) + c_2 TFP_{it} + c_3 Market_{it} \\ &+ \gamma \text{control}_{it} + \delta_f + \delta c \delta s + \delta_t + varepsilon_{it} \end{aligned} \quad (4)$$

TFP_{it} is the firm's total factor productivity. This study uses the LP method (Levinsohn and Petrin, 2003) to measure TFP. The LP method does not need to use the investment amount as a proxy variable and instead uses the intermediate product input indicator, which is more easily obtained. Most of China's industrial firms do not have complete information on short- or long-term investments. If the OP method is selected, a large amount of sample information will be wasted. $Market_{it}$ indicates the size of the firm's market. The market size corresponding to each firm is obtained by weighting and adding up the actual GDP of the country where the products are exported. The actual GDP of the destination country comes from the Penn World Table and the UNCTAD database.

5.2. Results of the mediation effect model

From the analysis of the theoretical mechanism, it is known that firm exports mainly promote firm innovation by increasing the productivity of firms and expanding the scale of the firm's market. This study adopts the mediation effect model to test these two channels, and reruns equations (2), (3) accordingly. Columns (1)-(5) of Table 8 report the regression results of the core explanatory variable, Export, the mediation variable TFP, and the variable $Market$ for the explained innovation variable. In column (1) of Table 8, the estimated coefficient of the export of the firm is significantly positive at the 1% significance level, indicating that firms' participation in exports significantly improves their productivity. With regard to the export learning effect, Chinese export firms gain international experience and knowledge of advanced technology through their exports, which help improve their productivity. Column (3) of Table 8 shows that $Export$ is significantly positive at the 1% level, indicating that firms' participation in exports expands the size of the firm's market. After adding the intermediate variables TFP in column (2) and Market in column (4), the regression coefficient of the core variable Export decreased, compared with the baseline regression, while the TFP and $Market$ regression coefficients became significant.

We use Sobel's (1987) method to test whether the two mediating effects are significant. The specific method requires testing whether the regression coefficient product term on the path through the mediation variable is significant, that is, by testing $H0$: $a_1c_2 = 0$ and $b_1c_3 = 0$. If $H0$ is rejected, then the mediation effect is significant. We calculate the standard deviation: $S_{a_1c_2} = \sqrt{a_1^2S_{c_2}^2 + c_2^2S_{a_1}^2}$, $S_{b_1c_2} = \sqrt{b_1^2S_{c_3}^2 + c_3^2S_{b_1}^2}$, where S indicates the standard error corresponding to the relevant regression coefficient.

According to the regression results in Table 8, the standard errors of the product terms 6.81×10^{-5} and 1.27×10^{-4} are calculated as a_1c_2 and b_1c_3, respectively. Further, according to the formula $Z_{a_1c_2} = \hat{a}_1\hat{c}_2/S_{a_1c_2}, Z_{b_1c_3} =$

TABLE 8.

Mechanism test results of firm exports' effect on firm innovation (mediation effect model)

	(1) TFP	(2) Innovation	(3) Market	(4) Innovation	(5) Innovation
Export	0.0140***	0.1217***	0.0174***	0.1228***	0.1204***
	(0.0004)	(0.0018)	(0.0003)	(0.0018)	(0.0018)
TFP		0.0631***			0.0265***
		(0.0041)			(0.0048)
Market				0.1156***	0.0989***
				(0.0058)	(0.0071)
Size	0.3626***	0.1772***	0.5482***	0.1328***	0.1360***
	(0.0027)	(0.0075)	(0.0025)	(0.0077)	(0.0079)
Finance	0.3584***	0.1915***	0.4921***	0.1492***	0.1556***
	(0.0146)	(0.0490)	(0.0107)	(0.0482)	(0.0490)
Wage	0.3027***	0.0254***	0.2839***	0.0126*	0.0081
	(0.0023)	(0.0066)	(0.0019)	(0.0066)	(0.0067)
Profit	1.9608***	0.0484	1.3062***	0.0196	−0.0111
	(0.0138)	(0.0347)	(0.0087)	(0.0335)	(0.0350)
Age	0.0341***	−0.0418***	0.0301***	−0.0424***	−0.0431***
	(0.0018)	(0.0067)	(0.0013)	(0.0066)	(0.0067)
Cons	4.3358***	−0.8417***	6.5189***	−1.3087***	−1.3263***
	(0.0157)	(0.0486)	(0.0146)	(0.0598)	(0.0619)
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes
Region-fixed effects	Yes	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes	Yes
N	1072963	845142	1101851	869964	845142
R^2	0.831	0.734	0.936	0.731	0.734

Note: Standard errors are in parentheses; ***, **, and * indicate significance levels at 1%, 5%, and 10%.

$\hat{b}_1\hat{c}_3/S_{b_1c_3}$, the values of $Z_{a_1c_2}$ and $Z_{b_1c_3}$ are calculated to be 5.45 and 13.55, respectively. The 5% significance level is statistically significant. These results further illustrate that the export learning effect and market scale expansion effect are important channels for firm exports to influence firm innovation. To compare the relative magnitudes of the export learning effect and the market size expansion effect, we refer to the method of Wen Zhonglin (2004): $Effect_{tfp} = \hat{a}_1\hat{c}_2/\hat{c}_1$, $Effect_{market} = \hat{b}_1\hat{c}_3/\hat{c}_1$, to calculate the proportion of the mediating effect in the total effect. According to Table 8, the relative magnitudes of the export learning effect and mar-

ket scale expansion effect are 3.08×10^{-3} and 1.43×10^{-2}, respectively, indicating that the latter is greater than the former.

6. CONCLUSIONS

This study uses the 2001-2007 China Industrial Firm Database and China Customs Trade Database to test empirically the impact and internal mechanism of Chinese firms' participation in export innovation. The results show that first, the participation of firms in exports is an important factor in stimulating the innovation and improvement of Chinese firms, and this result is robust. Second, the test results of the related mechanisms indicate that through the export learning effect, firm innovation not only enhances the productivity of firms but also the innovation capability of these firms. Furthermore, firm innovation increases the scale of the firm's market through the market scale expansion effect, thus stimulating firms to innovate continuously. However, the export learning effect is smaller in magnitude than the market size expansion effect.

The policy implications and recommendations are as follows.

(1) Encourage firms to follow the path of internationalization. Due to historical and institutional reasons, China's manufacturing industry currently lags behind the manufacturing firms of developed countries. By formulating an international business strategy, Chinese firms can not only learn advanced foreign management practices and production technology, but also enter foreign markets and compete with foreign firms on a global scale. To gain a competitive advantage, firms are more likely to continue to enhance their innovation capabilities.

(2) Continue to encourage firms' participation in exports. Under the current policy of actively expanding domestic demand, we cannot ignore the strong attraction of exports. Firm participation in exports is seen as a strategic act by firms for carrying out innovative activities to enhance their international competitiveness. The government is constantly encouraging local firms to "go global" while improving their willingness and ability to innovate — encouraging export firms to innovate and innovative firms to export more in a virtuous cycle — thereby accelerating the performance of manufacturing firms in China. The pace of transformation and upgrading will break through the existing "low-end lock" global value chain predicament.

(3) Maintain the global free trade system and promote the building of a community of shared future for mankind. Under the new situation, global trade protectionism has risen, the voices of opposition to free trade have emerged from time to time, and trade friction has slowed the growth of global trade. As one of the beneficiaries of globalization, we should always be the defender and advocate of global free trade. we should contribute to

the promotion and development of global free trade, promote new ways for global economic cooperation, and promote the development of global trade in an inclusive and mutually beneficial manner.

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