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Navigating Trade Facilitation: A Catalyst for Export Technological Complexity of Chinese Manufacturing Firms

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Abstract

The enhancement of export technological complexity in manufacturing enterprises is a crucial measure to facilitate the transformation and upgrade of manufacturing firms towards high-quality development. This paper delves into the mechanism through which trade facilitation impacts the export technological complexity of manufacturing enterprises. Empirical tests are conducted using matched data from China's industrial enterprise database, customs database, and enterprise patent database spanning from 2004 to 2013. The key findings are as follows: 1) Although both trade facilitation and export technological complexity of manufacturing enterprises are on the rise, the gap in trade facilitation among enterprises is continuously narrowing, while the gap in export technological complexity is expanding. 2) Trade facilitation, along with its various indicators, positively influences the enhancement of export technological complexity in manufacturing enterprises, with the impact influenced by enterprise heterogeneity and geographical location. 3) Trade facilitation primarily improves the export technological complexity of manufacturing enterprises through effects such as cost reduction, technological innovation, competition, and enhanced productivity. 4) Resource reallocation emerges as a significant mechanism through which trade facilitation fosters the enhancement of export technological complexity in manufacturing enterprises, facilitating the transfer of resources from enterprises with low technological complexity to those with high technological complexity.

Keywords

Trade Facilitation, Manufacturing Enterprises, Export Technological

Complexity, Resource Reallocation

1. Introduction

Hausmann and Rodrik (2003) introduced the concept of export technological complexity to measure the technological sophistication of exported goods. Hausmann et al. (2007) developed a metric for export technological complexity, which serves as a gauge for a country's export competitiveness and industrial advancement. Widely adopted, this index plays a pivotal role in assessing both a country's export product sophistication and its international competitive standing. Utilizing this measure to evaluate China's trade performance post its WTO accession, it becomes evident that China's export portfolio's technological complexity has notably surged, ascending from the top 36th in 2001 to the top 16th in 2019. This underscores significant enhancements in China's manufacturing processes, the technological depth of its exports overall, restructuring of its economic landscape, and the overall quality of its economy.

As China's manufacturing sector evolved and its trade volume expanded, scholars turned their attention to analyzing the measurement of China's export complexity and the factors shaping it. Hausmann et al. (2005) and Schott (2008) observed that China's export technological complexity rivaled that of certain developed nations and approached that of OECD countries. Rodrik (2006) termed the discrepancy between China's export technological complexity and its economic development level the "puzzle of export technological complexity growth".

Existing research on export technological complexity predominantly concentrates on the level of export products or industries, with limited efforts directed towards conducting systematic analyses at the enterprise level. Furthermore, studies conducted at the enterprise level have highlighted that trade barriers, uncertainties in trade policies, environmental regulations, and intellectual property protection can influence the technological complexity of exporting firms (Zhang et al., 2019; Cipollina & Demaria, 2020; Gandhi & Ahmed, 2020; Kingsley-Omoyibo, 2021). However, there is a dearth of research on the impact of trade facilitation on enterprise technological complexity. Trade facilitation, recognized as a crucial measure for reducing trade costs, enhancing trade efficiency, and expanding trade scale, plays a significant role in decreasing transaction and transportation costs while improving product quality (Fu et al., 2023; Dennis & Shepherd, 2011). Thus, in the study of enterprises' export technological complexity, the role of trade facilitation should not be overlooked.

Lin's new structural economics theory posits that convergence between developing and developed economies necessitates the accumulation of capital according to their comparative advantages (Haouas & Lin, 2024). This gradual process involves improving resource endowments to develop new comparative advantages, ultimately leading to catch-up. The enhancement of China's trade infrastructure has facilitated trade across various sectors and to varying degrees, aiding Chinese enterprises in establishing comparative advantages in exports (Li & Li, 2024). Despite China is still a developing country, its export enterprises can leverage the comparative advantage provided by trade facilitation. Through this, they can incrementally amass capital and technology, thereby enhancing the technical complexity of their export products. Aligning with these principles, studying the impact of China's trade facilitation on the export technological complexity of enterprises can, to some extent, address the puzzle of export technological complexity growth proposed by Rodrik.

This paper aims to investigate the shifts in export technological complexity resulting from the influence of trade facilitation. Specifically, it seeks to analyze the impact of trade facilitation on export technological complexity using enterprise-level data on Chinese manufacturing. The objective is to unveil the mechanism through which China enhances trade facilitation by minimizing the distance between companies and ports, thereby assisting Chinese manufacturers in augmenting the technological sophistication of their exports.

Specifically, this study empirically examines matched data from the China Industrial Enterprise Database, Customs Database, and enterprise patent database spanning from 2004 to 2013. It investigates the impact of trade facilitation on the export technological complexity of China's manufacturing enterprises. The contributions of this paper are as follows. We introduced a novel approach to measure the level of trade facilitation of enterprises. This paper involves constructing provincial-level trade facilitation indicators and analyzing the geographical coordinates of industrial enterprises using the Autonode interface and geocoding. The reciprocal of the distance between each sample enterprise and its nearest port is calculated through geography-based calculations, thereby determining the trade facilitation level of each enterprise. We measured the export technological complexity at the enterprise level by utilizing the ratio of the number of patent applications of enterprises to the average number of patents of enterprises in the industry as the weight, is measured. In addition, for the first time at the enterprise level, we examined the relationship between trade facilitation and export technological complexity of manufacturing enterprises.

The remainder of this article is structured as follows. Section II reviews the existing literature on trade facilitation and export technological complexity, elucidating the theoretical significance of this study. Section III delves into the mechanisms underlying the impact of trade facilitation on export technological complexity and proposes potential theoretical hypotheses. In Section IV, the research model, methods, data sources, and key indicators for measuring and characterizing facts are introduced. Section V empirically examines the impact of China's trade facilitation on the technological complexity of manufacturing exports and validates the hypotheses. Finally, Section VI presents the conclusion and recommendations derived from this study.

2. Literature Review

Since the inception of the concept of export technological complexity, scholars have extensively delved into two main areas of academic exploration. Firstly, they have elucidated the connotation of export technological complexity and measured its index by amalgamating various theories. Secondly, scholars have conducted analyses of the mechanisms and empirical tests of diverse factors influencing export technological complexity (Liang & Tan, 2024).

Hausmann and Rodrik (2003) pioneered the concept of export technological complexity as a metric for assessing the quality composition of individual economies' exports. Hausmann et al. (2007) further elaborated on this concept, asserting that a higher proportion of high-technology products in a country's export portfolio indicates higher export technological complexity. This method enables the measurement and comparison of the technical content and export quality of products. Xie and Zheng (2019) applied Hausmann's measurement method to analyze the structure and technology content of mechanical and electrical product exports from China, Japan, and South Korea between 2000 and 2016. Their findings revealed that while China's export technological complexity in this sector has increased, it still lags behind that of Japan and South Korea.

However, Hausmann et al. (2007) method of measuring export technological complexity has a notable limitation: it does not account for differences in product quality between countries. This oversight can result in significant errors in the measurement results. To address this, Xu (2010) introduced a relative price index to adjust for product quality variations across countries, enabling a more accurate measurement of export technological complexity. Subsequently, Yu and Yu (2018) utilized corporate Total Factor Productivity (TFP) to gauge the technological complexity of exports. This evolution in the method of measuring export technological complexity has gradually gained traction in academic circles.

Regarding the influencing factors of export technological complexity, scholars have proposed various perspectives. The formation of export technological complexity is attributed to the export product structure of the economy. Abdon and Felipe (2011) analyzed the product mix and comparative advantages of Sub-Saharan African countries, concluding that their comparative advantages were primarily in low-technology, low-value-added primary products, resulting in stagnant technological sophistication in their exports. Zhao et al. (2024) found that cost effects and market competition effects determine the structure of the upper and lower reaches of the value chain, thereby influencing the technological content of products and leading to varying levels of export technological complexity.

Export technological complexity stems from the accumulation of productive capacity. Hidalgo et al. (2007) and Hidalgo and Hausmann (2009) explain economic development as the process of learning how to produce more complex products. They argue that achieving increased technological sophistication in exports requires acquiring a complex set of capabilities to transition to the production of more complex products. Research by Mewes and Broekel (2022) further underscores the role of productive capacity in contributing to export technological complexity. Their findings emphasize that increasing technological complexity necessitates the attraction of qualified talent and integration into interregional knowledge networks. Moreover, more specific factors, including FDI, production segmentation, intellectual property protection, digital trade, and the digital economy, all play varying roles in shaping export technological complexity (Xu & Lu, 2009; Zhang & Yang, 2016; Díaz-Mora & García López, 2019; Lai et al., 2020; Rodríguez-Crespo & Martínez-Zarzoso, 2019; Meltzer, 2019; Liu et al., 2023). Some scholars also highlight the inhibiting effects of trade tariffs (Nguyen, 2016) and restrictions on trade in services (Su et al., 2020) on export technological complexity.

However, much of the existing research remains at the macro-level, with insufficient attention given to the role of individual enterprises in production and innovation. Furthermore, the significance of trade facilitation levels as a crucial indicator in research on the influencing factors of export technological complexity is often overlooked. Trade facilitation, recognized as a pivotal factor in enhancing export efficiency, reducing export costs, and fostering technological development of enterprises (Kanybekov & Inaba, 2023), has the potential to significantly enhance the competitiveness of products within the host country's economic landscape (Jarreau & Poncet, 2012). Therefore, investigating the mechanism of trade facilitation's impact on firms' export technological complexity could offer substantial insights and potentially provide answers to Rodrik's puzzle of export technological complexity growth.

As of now, a clear and standardized definition of trade facilitation remains elusive. The concept, initially introduced by the WTO during its Ninth Ministerial Conference in Singapore in 1996, generally refers to the simplification, modernization, and harmonization of import and export procedures. However, different economic organizations define trade facilitation according to their specific needs and concerns, leading to variations in identified impact factors. Initially, scholars identified infrastructure development to facilitate goods transport and technology diffusion as key components of trade facilitation (Egger et al., 2023; Mitchell & Mishra, 2020; Coşar et al., 2022). For instance, Karymshakov and Sulaimanova (2023) found that the cost and speed of travel at border crossings are crucial factors for trade facilitation among the five countries in Central Asia Regional Economic Co-operation (CAREC) when measuring the level of trade facilitation. In addition to tangible elements, scholars have explored the role of intangible elements in trade facilitation. For example, studies on the relationship between port efficiency and enterprise import costs have highlighted the significant impact of ineffective port on increasing trade costs and transportation time, thus reducing the level of trade facilitation (Liu & Yue, 2013; Feenstra & Ma, 2014). Moreover, the institutional environment plays a crucial role in enhancing trade facilitation by simplifying trade procedures, enhancing institutional transparency, and reducing trade costs (Fu, 2020; Marel & Shepherd, 2020). Changes in border management are also essential for ensuring the smooth functioning of trade channels and are thus an integral aspect of trade facilitation (Ramasamy & Yeung, 2019). In summary, factors that influence the flow of import and export products serve as indicators to measure the level of trade facilitation. This paper adopts the geographical distance of export enterprises to ports in China as a proxy variable to measure trade facilitation, which provides a novel perspective on trade facilitation measurement.

Although the indicators of the trade facilitation evaluation system vary, the basic directions are similar, and the measurability of trade facilitation is recognized worldwide. Trade facilitation indicators have also been widely used in trade studies. In a study of trade volumes, Moïsé and Sorescu (2013) used the components of trade facilitation as explanatory variables and found that the availability of information, the simplification of documents, and the flowability and automation of procedures had a significant impact. Trade facilitation measures such as non-tariff barriers to trade and institutional coordination have the greatest impact on trade flows in the 10-member Association of Southeast Asian Nations (ASEAN) (Thu & Thanh, 2021). In the study of export enterprises, Fontagné et al. (2020) found that trade facilitation measures such as pre-adjudication, appeal procedures, and automation tend to favor large exporters. Trade facilitation has had a positive impact on the export diversification of Sub-Saharan, Latin American, and Caribbean enterprises (Beverelli et al., 2015). These studies expand the scope of trade facilitation research, but still primarily focus on the country and industry perspective, with relatively limited emphasis on the enterprise level.

In summary, while research on export technological complexity and trade facilitation in their respective domains continues to advance, there remains a significant gap in understanding the impact of trade facilitation on enterprise export competitiveness. This paper seeks to address this void by examining the influence of trade facilitation on the export technological complexity of Chinese manufacturing enterprises. The aim is to offer a theoretical and empirical foundation that can guide other developing economies in their efforts to achieve trade quality convergence with developed economies.

3. Mechanism and Theoretical Assumptions

According to existing research findings, trade facilitation may not only directly affect the export technological complexity of manufacturing enterprises but also indirectly influence it through other transmission pathways.

3.1. The Direct Influence Mechanism of Trade Facilitation on the Export Technological Complexity of Manufacturing Enterprises

Previous studies have demonstrated that enhancements in various aspects of trade facilitation indicators (such as infrastructure, port efficiency, institutional environment, e-commerce, and marketization process) can directly foster the export technological complexity of manufacturing enterprises. Improvements in infrastructure can effectively reduce enterprises' transportation costs during bilateral trade, thereby enhancing their profitability and subsequently boosting the export technological complexity of manufacturing enterprises (Yu & Li, 2016). Enhanced port efficiency can significantly reduce customs clearance times for enterprises, thereby decreasing export product losses and increasing export frequency, thus positively impacting the export technological complexity of manufacturing enterprises (Hornok & Koren, 2015). Improvements in the institutional environment can effectively enhance the business environment for enterprises, thereby stimulating technological innovation in manufacturing enterprises. The development of e-commerce has notably lowered barriers to technology transmission and technology spillover among enterprises, expediting the transfer of technology from enterprises with high technological complexity to those with low technological complexity. Building upon these findings, this paper proposes Research Hypothesis 1:

Hypothesis 1: Improvement in trade facilitation has a positive effect on the export technological complexity of manufacturing enterprises.

3.2. The Indirect Influence Mechanism of Trade Facilitation on the Export Technological Complexity of Manufacturing Enterprises

Previous studies have demonstrated that trade facilitation can enhance the export technological complexity of manufacturing enterprises through various pathways, including the cost reduction effect, technological innovation effect, competition effect, and productivity improvement.

From the perspective of the cost reduction effect, cost reduction can effectively enhance the efficiency of enterprise resource allocation, bolster enterprises' ability to withstand market risks, and optimize factors of production, consequently improving enterprises' export technological complexity (Lei & Lang, 2020). Improvement in trade facilitation can effectively reduce transportation costs, cross-border transaction costs, and information acquisition search costs during bilateral trade, thereby lowering the cost of innovation and knowledge transfer. This reduction in costs breaks down trade barriers for enterprises, fosters economies of scale, and thus promotes the enhancement of enterprises' technological complexity (Yao, 2022). As trade facilitation improves, the cost of production segmentation for enterprises decreases continuously, leading to deeper production segmentation among enterprises. When the cost of outsourcing auxiliary production activities to downstream production enterprises is lower than the cost of in-house production, enterprises will reduce production costs by outsourcing. This allows enterprises to focus on research and development and the production of core products, thus facilitating continuous improvement in technological complexity (Dong, 2022). Additionally, improvement in trade facilitation can enhance export technological complexity by shortening procurement lead times, reducing safety inventory, and lowering inventory costs for enterprises (Duan & Jing, 2021).

From the perspective of the technological innovation effect, improvements in trade facilitation can effectively reduce consumer product prices, indirectly increase consumer income levels, and stimulate demand for diverse imported products. The influx of numerous new products expands learning opportunities for enterprises. Enterprises enhance the technological complexity of exports through learning effects and technology spillovers (Xu et al., 2017). As the value chain embedment deepens, linkages between enterprises at different positions in the value chain become more frequent. Enhanced trade facilitation accelerates industrial agglomeration formation. To enable downstream industries to effectively produce intermediate products for upstream industries, the latter may share some non-core key technologies with the former, thus improving the technological complexity of downstream industries (Wang & Zheng, 2019). Improved trade facilitation is conducive to breaking down trade barriers and promoting technological innovation. Specifically, e-commerce development in trade facilitation effectively reduces inter-enterprise technology transmission and spillover costs, fostering more frequent inter-enterprise technology exchange and enhancing technology sharing and diffusion capabilities. This leads to improved innovation capability, efficiency, and export technological complexity of enterprises (Lei & Lang, 2020; Lu & Jin, 2020).

From the perspective of the competition effect and enterprise productivity, improved trade facilitation encourages more enterprises to engage in multilateral trade, leading to a rapid increase in the number of enterprises within the same industry. According to market competition theory, more enterprises lead to fiercer market competition. To cope with this competition, enterprises import more advanced machinery and equipment to gain technical advantages from capital elements. Additionally, enterprises may increase research and development (R&D) activities and expenditures to consolidate or expand market share, thus raising competitors' entry thresholds within the same industry and increasing export technological complexity (Zhao, 2020). Mayer's empirical model suggests that improved trade facilitation intensifies the market competition environment in product-producing countries, reducing enterprise cost markups. Multi-product producers decrease the production of low-productivity products and concentrate on core products with high productivity, resulting in a "skew effect" within the enterprise. By allocating more resources to core products with higher productivity and optimizing resource allocation within the enterprise, overall enterprise productivity can be effectively enhanced, thereby increasing export technological complexity (Mayer et al., 2014).

Based on the above analysis, this paper proposes Research Hypothesis 2:

Hypothesis 2: Improvement in trade facilitation will positively affect the export technological complexity of enterprises through cost effects, technology effects, competition effects, and improvements in firm productivity.

3.3. Model Building

Based on the above theories and assumptions, to explore the ways to maximize the improvement of export technological complexity of manufacturing enterprises, this paper constructs the following models (such as Equations (1) and (2)) to empirically test the relationship between trade facilitation and export technological complexity of manufacturing enterprises.

$$CETC_{ikjt} = \alpha_0 + \alpha_1 Tf_{ikjt} + \delta_m X_{ikjt} + \mu_f + \mu_t + \varepsilon_{ikjt} \quad (1)$$

$$\begin{aligned} CETC_{ikjt} = {} & \beta_0 + \beta_1 Infra_{ikjt} + \beta_2 Port_{ikjt} + \beta_3 Insti_{ikjt} + \beta_4 Elec_{ikjt} \\ & + \beta_5 Market_{ikjt} + \delta_m X_{ikjt} + \mu_f + \mu_t + \varepsilon_{ikjt} \end{aligned} \quad (2)$$

The above formula indicates as follows: i represents the region in which the enterprise operates, k denotes the industry identifier for the enterprise, j stands for individual enterprises, and t represents time. α_1 is the regression coefficient for trade facilitation, $\beta_1 \sim \beta_5$ is the regression coefficients for various indicators of trade facilitation, α_0, β_0 is the constant term, X denotes control variables, δ_m represents the regression coefficients of control variables, μ_f and μ_t are enterprise fixed effects and time fixed effects respectively, and ε_{ikjt} is the random disturbance term.

4. Key Indicators

4.1. Data Sources

The measurement data of trade facilitation are obtained from various sources including provincial statistical yearbooks, China Port Yearbook, China Marketization Index Report, China Internet Network Information Center, and State Intellectual Property Office Statistical Yearbook. The reciprocal distance between the enterprise and the nearest port is calculated by the author using AutoNavi map API and geocoding, utilizing geographical calculation.

The data for export technological complexity were sourced from the China Industrial Statistics Yearbook, China Economic Census Yearbook, and customs database. Enterprise patent data were obtained from the CPDP (Chinese Patent Data Project) and the patent database of the State Intellectual Property and Patent Office of China.

The measurement data of control variables and intermediary variables were derived from the China Industrial Enterprise Database and customs database. Descriptive statistics of the data are presented in Table 1.

Table 1. Descriptive statistics of variables.

Type of variables	Variable	Number of observations	Mean	Standard deviation	Minimum	Maximum
Explained variable	*CETC*	83,660	11.504	1.899	2.129	20.759
Explanatory variables	*Tf*	83,660	2.083	1.400	7.789	3.973
	Infra	83,660	0.914	1.128	5.684	0.103
	Port	83,660	1.353	1.222	8.732	0.204
	Insti	83,660	0.535	0.539	3.897	0.000
	Elec	83,660	0.835	0.596	4.319	0.137
	Market	83,660	0.184	0.209	2.951	0.309

Continued

Control variables	*Size*	81,850	6.007	1.087	0.000	12.145
	Age	83,628	2.320	0.650	0.000	7.607
	Otfp	83,660	5.314	1.208	3.816	10.681
	Gsub	82,820	0.004	0.022	0.218	1.580
	Fcs	82,847	0.012	0.018	0.379	1.148
Mediating variables	*Cost*	74,843	0.046	0.058	0.082	1.721
	Input	69,057	7.382	2.273	0.000	15.782
	Ics	73,901	0.020	0.058	0.010	1.635
	Ltfp	83,660	5.028	1.308	2.916	11.037

4.2. Measurement of Key Indicators

1) Trade facilitation

This paper adopts the multi-field scoring method to assess trade facilitation across various provinces. Existing studies have indicated that the development disparity between northern and southern regions of China has shifted from differences in natural environments to disparities in the extent of market-oriented development. Therefore, building upon the research by Duan et al. (2020), this paper selects infrastructure, port efficiency, institutional environment, e-commerce, and market-oriented processes as the measurement indicators for trade facilitation. Subsequently, proxy variables or secondary indicators are utilized to score each indicator individually, followed by standardization processing to gauge the level of trade facilitation in each province. The standardization formula is presented in Equation (3):

$$z_{dt} = \frac{X_{dt} - \min X_{dt}}{\max X_{dt} - \min X_{dt}} \times 10 \tag{3}$$

In which X_{dt} stands for the standardized object, and Z_{dt} represents the standardized index. The measurement variables and data sources for each indicator are detailed in Table 2.

Table 2. Measurement indicators of trade facilitation.

Primary Indicators	Secondary indicators	Data source	References
Infrastructure	Provincial highway mileage	Provincial Statistical Yearbooks	Wilson et al. (2003, 2005), Yin et al. (2016), Duan et al. (2020)
	Provincial railway mileage	Provincial Statistical Yearbooks	
	Provincial inland waterway mileage	Provincial Statistical Yearbooks	
Ports Efficiency	Ratio of total import and export value through ports to total import and export value of the province	China Port Yearbook	
Institutional Environment	Development of market intermediary organizations and legal environment	China Marketization Index Report	
	Strength of intellectual property protection (number of patents granted in each province)	National Intellectual Property Administration Statistical Yearbook	

Continued

Electronics Commerce	End-of-year mobile phone users	Provincial Statistical Yearbook
	Internet penetration rate	China Internet Network Information Center
Marketization process	Marketization Index	China Marketization Index Report

Based on measuring the level of provincial trade facilitation, this paper utilizes the AutoNavi map API and geocoding to analyze the longitude and latitude of office addresses of enterprises. This is done after matching China's industrial enterprise database, customs database, and patent database from 2004 to 2013. The reciprocal distance of enterprises from the nearest port is then obtained through geographical calculation. The trade facilitation index of each enterprise is calculated using this distance as the weight. The calculation formula is shown in Equation (4):

$$Tf_{ikjt} = Tf_{ikjt} \times 1/Dis_{si} \tag{4}$$

Tf_{ikjt} represents the level of trade facilitation for enterprise j in industry k in region i in year t, Tf_{jt} represents the level of trade facilitation for province j in year t, and Dis_{si} represents the distance of enterprise i to its nearest port s.

2) Technological complexity of exports

Regarding the measurement of export technological complexity, the two-step method proposed by Hausmann et al. (2007) has been widely used in most studies to measure the technological complexity of exports at the national or regional level. Since the quality of products exported by different countries may vary greatly, most existing studies refer to the research results of Xu (2010) to introduce a relative price index to adjust the export technological complexity of different countries. However, the differences in the quality of export products in different regions of the same country are usually small. Therefore, this paper uses Hausmann's two-step method for reference (Lei & Lang, 2020) to measure the export technological complexity of different provinces. The first step is to measure the technological complexity of exports of manufacturing enterprises at the industry level. The measurement formula is shown as Equation (5):

$$IETC_{kt} = \sum_i \frac{x_{ikt}/X_{it}}{\sum_i \left(x_{ikt}/X_{it}\right)} \times Y_{it} \tag{5}$$

where $IETC_{kt}$ represents the export technological complexity of industry k in year t, x_{ikt} represents the total exports of industry k in region i in year t, X_{it} represents the total exports of all manufacturing industries in region i in year t, and Y_{it} is the per capita GDP of region i in year t. In the second step, based on formula (5), the proportion of exports of various industries in the total exports of all manufacturing industries is calculated. This proportion is then used as a weight to calculate the export technological complexity of manufacturing enterprises at the provincial level. The calculation formula is as follows:

$$PETC_{it} = \sum_k \frac{x_{ikt}}{X_{it}} \times IETC_{kt} \tag{6}$$

where $PETC_{it}$ represents the export technological complexity of region i in year t. Since the number of patents applied by enterprises can reflect the innovation ability and R&D investment level of enterprises to a large extent, generally, the more patents applied by enterprises, the higher the export technological complexity of enterprises in the industry. Therefore, this paper uses the ratio of the number of patents applied by enterprises to the average number of patents applied by enterprises in the industry as the weight to measure the export technological complexity at the enterprise level. The specific measurement formula is shown in Equation (7):

$$CETC_{ikjt} = \frac{Pat_{ikjt}}{\sum_j Pat_{kjt} / n} \times PETC_{it} \tag{7}$$

where $CETC_{ijkt}$ represents the export technological complexity of enterprises j in industry k in region i in year t, Pat_{ikjt} represents the number of patents obtained by enterprises j in industry k in region i in year t, Pat_{kjt} represents the number of patents obtained by enterprises j in industry k in year t, and n is the number of enterprises in the corresponding industry.

4.3. Analysis of Typical Facts

According to the above determined measurement method, this paper measures the trade facilitation and export technological complexity of enterprises by matching the Chinese industrial enterprise database, customs database, and enterprise patent database from 2004 to 2013. The relevant typical facts are as follows:

1) Both trade facilitation and export technological complexity are optimized to varying degrees

Observing **Figure 1**, it is evident that from 2004 to 2013, the enterprise trade facilitation level exhibits several characteristics: Firstly, the peak of the kernel density plot for enterprise trade facilitation consistently shifts towards the right. This indicates continuous improvement in the trade facilitation level of China's manufacturing enterprises and ongoing optimization of their export environment. Secondly, the kernel density plot for enterprise trade facilitation transitions from a "wide and short peak" to a "high and narrow peak", suggesting a narrowing gap in trade facilitation among enterprises.

Turning to **Figure 2**, the export technological complexity of China's manufacturing enterprises during 2004-2013 demonstrates the following features: Firstly, the peak of the kernel density plot for export technological complexity steadily moves towards the right, indicating a yearly increase in export technological complexity and ongoing optimization of manufacturing enterprises' export structure. Secondly, the kernel density plot for export technological complexity evolves from a "high and narrow peak" to a "wide and low peak", indicating an expanding gap in export technological complexity among manufacturing enterprises. Thirdly, both left-tail skewness and right-tail skewness of the kernel density plot for export technological complexity are increasing, suggesting a growing polarization in export technological complexity among manufacturing enterprises. This implies an increase in the number of manufacturing enterprises with consistently low export technological complexity, as well as those with consistently high export technological complexity, acting as "leaders".

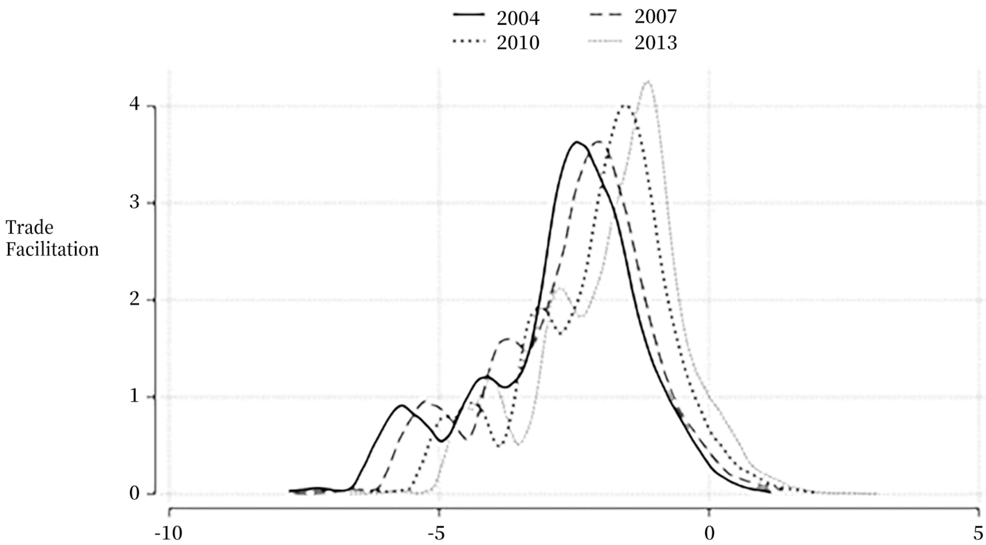

Figure 1. Kernel density plot of trade facilitation.

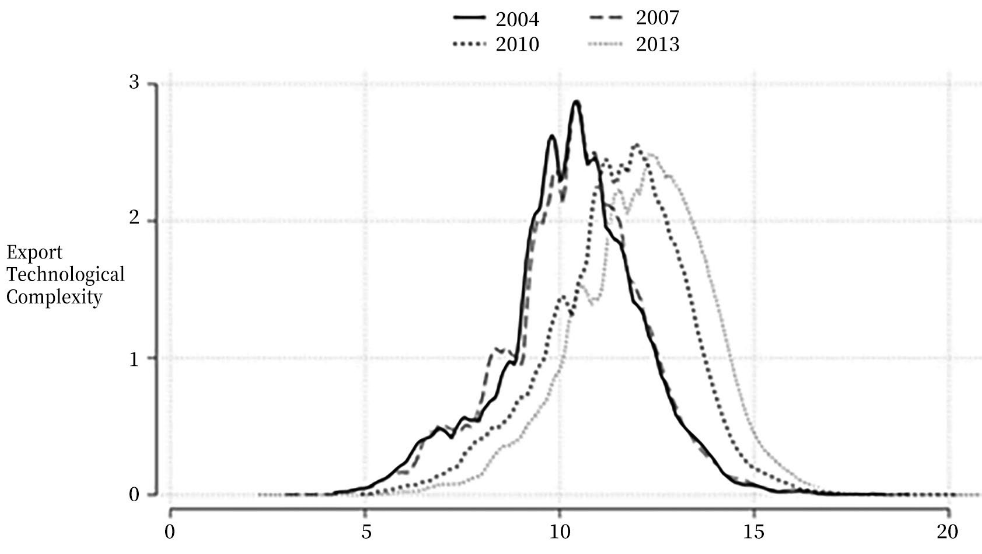

Figure 2. Kernel density plot of export technological complexity.

2) Trade facilitation and export technological complexity are demonstrable correlation

To illustrate the relationship between trade facilitation and export technological complexity from a macro perspective and provide a basis for constructing the empirical model, this paper presents a scatter plot of trade facilitation and export technological complexity (Figure 3). As depicted in Figure 3, trade facilitation and export technological complexity exhibit a positive correlation, with no non-linear relationship apparent.

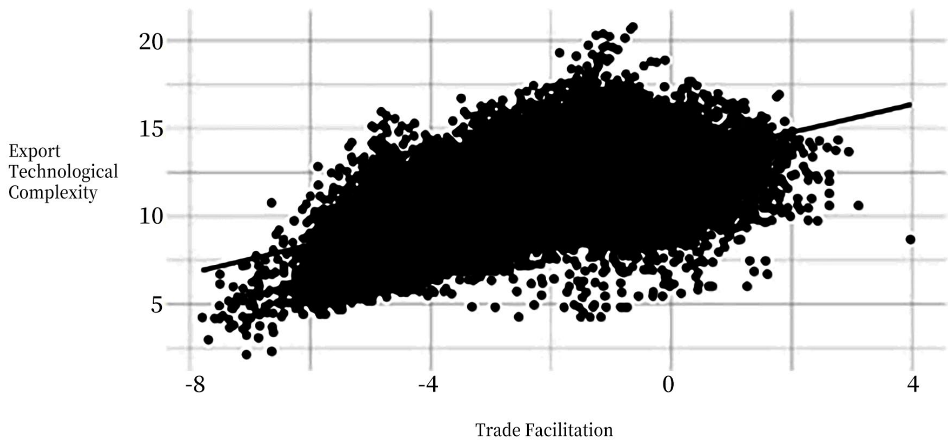

Figure 3. Linear fitting scatter plot of trade facilitation and export technological complexity of manufacturing enterprises.

5. Empirical Tests

5.1. Variable Selection

According to the research objectives of this paper, the export technological complexity of enterprises (*CETC*) is selected as the dependent variable. The independent variables include trade facilitation of enterprises (*Tf*) and various domain indicators of trade facilitation. These domain indicators encompass infrastructure (*Infra*), port efficiency (*Port*), institutional environment (*Insti*), e-commerce (*Elec*), and marketization process (*Market*). The values of enterprise-level trade facilitation domain indicators are represented by the reciprocal of the distance of enterprises to the nearest port multiplied by the provincial-level trade facilitation domain indicators. Both the dependent and independent variables are transformed into logarithmic values to eliminate dimensional differences.

Regarding control variables, this paper adopts the control variables selected by Gao and Yuan (2020), including enterprise size (*Size*), measured by the logarithm of the number of employees at the end of the year; enterprise age (*Age*), measured by the logarithm of the difference between the observation year and the year of establishment plus one; enterprise total factor productivity (*Otfp*), measured by the results of the OP method; government subsidies received by enterprises (*Gsub*), measured by the ratio of government subsidies received by enterprises in the observation year to the main business income of enterprises; and financing constraints (*Fcs*), measured by the logarithm of the ratio of interest expenses to total assets plus one.

Selection of Mediating Variables:

In order to empirically test the indirect effect of trade facilitation on the improvement of export technological complexity of manufacturing enterprises, this paper selects the following indicators as mediating variables based on the research results of Liu and Wang (2016) and others. The proportion of enterprise sales expenses to main business sales revenue (*Cost*) is used as the mediating variable for the cost reduction effect. The logarithm of enterprise research and development investment (*Input*) serves as the mediating variable for enterprise technological innovation effect. The Herfindahl-Hirschman Index (HHI) is calculated, and the proportion (*Ics*) of a single company's main business income to the total main business income of all companies in the same industry is used as the mediating variable for enterprise competitive effect. Enterprise total factor productivity (*Ltfp*) is chosen as the mediating variable for enterprise productivity. Since the enterprise total factor productivity measured by the OP method is already included in the control variables, the measurement results of enterprise total factor productivity using the LP method are utilized to measure the mediating variable of enterprise total factor productivity.

5.2. Empirical Results

1) Benchmark regression results

The corresponding LR test, F test, and Hausman test were conducted in this study, all of which rejected the null hypothesis of mixed regression at a significance level of 1%. Therefore, the fixed effects model was employed to estimate the model. The results of the baseline regression are presented in **Table 3**. Overall, across all models, trade facilitation consistently exhibits a positive effect on the export technological complexity of manufacturing enterprises, with a relatively stable effect magnitude. Specifically, the analysis of regression results in column (6) indicates a positive impact of trade facilitation on export technological complexity. A 1% increase in trade facilitation is associated with a 0.0751% increase in export technological complexity of manufacturing enterprises, which is statistically significant at the 1% level.

The above-mentioned tests confirm that the level of trade facilitation can promote the increase of export technological complexity of manufacturing enterprises, so hypothesis 1 is verified.

Regarding the control variables, both firm size and firm total factor productivity demonstrate a significant positive impact on the technological complexity of manufacturing exports. This can be attributed to the larger size and higher productivity of firms, which entail greater resource abundance, enhanced production efficiency, and increased availability of capital for research and development (R&D) and innovation activities. Consequently, these factors positively influence the export technological complexity of manufacturing enterprises. However, the impact of enterprise survival years on export technological complexity is only significant at the 10% level. Government subsidies and financing constraints exert a diminishing effect on the export technological complexity of manufacturing enterprises. Government subsidies may induce complacency within enterprises, diminishing their motivation for product innovation and technological complexity enhancement.

Conversely, financing constraints may curtail enterprises' investment in R&D funds, thereby impeding improvements in export technological complexity of manufacturing enterprises.

Table 3. Regression results of trade facilitation.

Variable names	Export technological complexity (*CETC*)						
	FE						*OLS*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tf	0.0896*** (4.19)	0.0984*** (3.78)	0.0993*** (4.31)	0.0794*** (3.78)	0.0745*** (4.69)	0.0751*** (4.71)	0.8336*** (26.60)
Size		0.0528*** (4.79)	0.0507*** (4.58)	0.0444*** (4.23)	0.0423*** (4.15)	0.0425*** (4.52)	0.2706*** (12.42)
Age			0.0415* (1.87)	0.0468* (1.73)	0.0386* (1.74)	0.0389* (1.91)	0.0486* (1.83)
Otfp				0.0212*** (7.06)	0.0186*** (5.11)	0.0184*** (9.36)	0.1275*** (9.38)
Gsub					0.0408 (−1.81)	0.0414 (−1.76)	0.0442 (−1.90)
Fcs						0.0294 (−7.14)	0.0187 (−8.70)
Number of observations	83,660	81,850	81,850	81,850	81,850	81,850	81,850
Corporate fixed effect	yes	yes	yes	yes	yes	yes	no
Time fixed effect	yes	yes	yes	yes	yes	yes	no
R^2	0.2639	0.3159	0.3182	0.3838	0.4186	0.4192	0.4506

Note: The t value is in parentheses, * where, **, and *** are significant at 0.1, 0.05, and 0.01 levels respectively. The following text is consistent with this.

2) Heterogeneity analysis

The impact of trade facilitation on the export technological complexity of manufacturing enterprises may vary significantly depending on factors such as ownership type, factor intensity, and geographical location. Therefore, this paper examines the heterogeneity among manufacturing enterprises with different ownership types, factor intensities, and geographical locations.

a) Enterprises of different ownership types

Manufacturing enterprises of different ownership types encounter distinct differences in institutional environments, government support, and resource availability. Accordingly, this paper categorizes manufacturing enterprises into state-owned enterprises, foreign-funded enterprises, and private enterprises, exploring the effects of trade facilitation on the export technological complexity within each ownership category. Table 4 presents the regression results of trade facilitation on the export technological complexity of manufacturing enterprises across different ownership types.

Table 4. Regression results of different types of enterprises.

Variable name	Export technological complexity (*CETC*)			
	Full sample	State-owned enterprises	Foreign-funded enterprises	Private enterprises
Tf	0.0751*** (4.71)	0.0014 (1.13)	0.0309* (1.86)	0.0812*** (6.57)
Control variables	Controls	Controls	Controls	Controls
Number of Observations	81,850	10,692	37,306	13,852
Corporate Fixed effect	yes	yes	yes	yes
Time Fixed effect	yes	yes	yes	yes
R^2	0.4192	0.3874	0.4108	0.4283

According to the regression findings, the positive impact of trade facilitation on the export technological complexity is most pronounced for private manufacturing enterprises, followed by foreign-funded enterprises. In contrast, the effect on the export technological complexity of state-owned manufacturing enterprises is comparatively smaller and statistically insignificant. This difference may primarily stem from the fact that state-owned enterprises, lacking incentives for technological and institutional innovation compared to non-state-owned ownership types (Li & Li, 2024), experience slower improvements in export technological complexity.

b) Enterprises with different factor intensities

Enterprises with different factor intensities may exhibit significant differences in product positioning, strategic orientation of export products, and the proportion of R&D investment. To address this, the paper divides the sample enterprises into capital-intensive and labor-intensive enterprises, respectively discussing the impact of trade facilitation on the export technological complexity under these two factor intensity conditions. The corresponding regression results are presented in **Table 5**.

Table 5. Regression results of firms with different factor intensities.

Variable name	Export technological complexity (*CETC*)		
	Full sample	Capital intensive	Labor intensive
Tf	0.0751*** (4.71)	0.0851*** (3.42)	0.0007 (1.27)
Control variables	Controls	Controls	Controls
Number of Observations	81,850	47,307	34,543
Corporate fixed effect	yes	yes	yes
Time fixed effect	yes	yes	yes
R^2	0.4192	0.4603	0.3819

According to the regression findings, trade facilitation positively influences the export technological complexity of capital-intensive manufacturing enterprises, with the effect being statistically significant at the 1% level. However, the promotional effect on the export technological complexity of labor-intensive manufacturing enterprises is not statistically significant. This may be attributed to the lower technical level of products produced by labor-intensive enterprises, resulting in slower technology updates and reduced sensitivity to changes in trade facilitation.

c) Enterprises in different geographical locations

Due to significant variations in the level of trade facilitation across the eastern, central, and western regions of China, there may exist regional disparities in the impact of trade facilitation on enhancing the export technological complexity of manufacturing enterprises. To address this, the study categorizes manufacturing enterprises into those situated in the eastern, central, and western regions, respectively, and examines the influence of trade facilitation enhancements on the export technological complexity within each region. The regression outcomes are presented in **Table 6**. The results indicate that the enhancement of trade facilitation exerts the most pronounced impact on elevating the export technological complexity of manufacturing enterprises in western China, followed by those in central China, while enterprises in eastern China exhibit the least significant effect.

Table 6. Regression results of enterprises in different geographical locations.

Variable name	Export technological complexity (*CETC*)			
	Full sample	Eastern enterprise	Central enterprises	Western enterprises
Tf	0.0751*** (4.71)	0.0102* (1.72)	0.0503** (2.81)	0.0902*** (5.17)
Control variables	Controls	Controls	Controls	Controls
Number of observations	81,850	71,506	6966	3378
Corporate fixed effect	yes	yes	yes	yes
Time fixed effect	yes	yes	yes	yes
R^2	0.4192	0.3806	0.4037	0.4381

3) Robustness test

To ensure the robustness of the research findings, this study conducts several robustness tests on the relationship between trade facilitation and the export technological complexity of manufacturing enterprises.

a) Substitution of Trade Facilitation Index

This paper substitutes the product market development score from the Fan Gang Marketization Index as the proxy variable for provincial trade facilitation. The trade facilitation level at the enterprise level is then calculated based on the reciprocal distance between each enterprise and the nearest port for regression analysis. The regression outcomes are presented in the first column of **Table 7**, demonstrating that the positive impact of trade facilitation on the export technological complexity of manufacturing enterprises remains significant.

b) Substitution of Export Technological Complexity Index

Recognizing that product quality often reflects the technical proficiency of an enterprise, this paper substitutes the product quality of enterprises as a proxy variable for the technological complexity of manufacturing export in the regression analysis. The product quality of manufacturing enterprises is quantified using the "demand residual method" introduced by Shi Bingzhan and Shao Wenbo. The results, depicted in the second column of **Table 7**, continue to exhibit significance in the regression outcomes.

c) Re-measurement of Export Technological Complexity

To further validate the regression findings, this study adopts the approach proposed by Yu and Yu (2018) to re-measure the export technological complexity of manufacturing enterprises. This method involves utilizing the ratio of total factor productivity (measured via the LP method) to the mean enterprise rate of the respective industry as the weight. The newly computed export technological complexity of manufacturing enterprises is then incorporated into the regression model for analysis. The results, displayed in the third column of **Table 7**, reaffirm the positive impact of trade facilitation on the export technological complexity of manufacturing enterprises.

Table 7. Robustness test results.

Variable names	(1)	(2)	(3)
Tf	0.0709*** (4.69)	0.0508** (2.59)	0.0812** (2.81)
Control variables	Controls	Controls	Controls
Number of observations	81,850	81,850	81,850
Firm fixed effect	yes	yes	yes
Time fixed effect	yes	yes	yes
R^2	0.4062	0.3971	0.4913

d) Regression Analysis Based on Different Patent Types

Moreover, this study employs the ratio of the number of patents of various types held by enterprises to the average number of corresponding patent types within the same industry as the weight. This measure is utilized to assess the export technological complexity of manufacturing enterprises across different patent categories, serving as the dependent variable for regression analysis. The regression outcomes are presented in **Table 8**, with columns (1) through (3) depicting the regression results for practical patents, design patents, and invention patents, respectively.

The findings reveal that trade facilitation exerts a positive influence on the export technological complexity of manufacturing enterprises across various patent types. Notably, the most pronounced effect is observed for practical patents, followed by design patents, whereas invention patents exhibit the least impact.

Table 8. Test results under different patent types.

Variable name	Export technological complexity (*CETC*)		
	(1)	(2)	(3)
Tf	0.0647*** (3.39)	0.0551* (1.75)	0.0469* (1.82)
Control variables	Controls	Controls	Controls
Number of observations	62515	25163	45820
Corporate fixed effect	yes	yes	yes
Time fixed effect	yes	yes	yes
R^2	0.4075	0.3816	0.3706

4) Mediation effect test

Based on the findings from the mechanism analysis, it is evident that trade facilitation not only directly enhances the export technological complexity of manufacturing enterprises but also indirectly contributes to this enhancement through several channels, including cost reduction, technological innovation, competition, and enhancement of total factor productivity. Therefore, following the mediation effect test method proposed by Sobel (1982), this paper develops an intermediary effect model (such as Equations (8)-(11)) to examine the mediating effects.

$$CETC_{ikjt} = \alpha_0 + \alpha_1 Tf_{ikjt} + \delta_m X_{ikjt} + \mu_f + \mu_t + \varepsilon_{ikjt} \tag{8}$$

$$CECT_{ikjt} = \gamma_0 + \gamma_n M_{ikjt} + \delta_m X_{ikjt} + \mu_f + \mu_t + \varepsilon_{ikjt} \tag{9}$$

$$M_{ikjt} = \sigma_0 + \sigma_n Tf_{ikjt} + \delta_m X_{ikjt} + \mu_f + \mu_t + \varepsilon_{ikjt} \tag{10}$$

$$CETC_{ikjt} = \lambda_0 + \lambda_1 Tf_{ikjt} + \lambda_n M_{ikjt} + \delta_m X_{ikjt} + \mu_f + \mu_t + \varepsilon_{ikjt} \tag{11}$$

In the equation above, i represents the region where the enterprise is located, k denotes the industry in which the enterprise operates, j stands for individual enterprises, and t represents the observation year. γ_0, σ_0 and λ_0 are constant terms, α_1, σ_n and λ_1 are the regression coefficients for trade facilitation, M is the mediating variable, X represents control variables, γ_n and λ_n are the regression coefficients for the mediating variables, δ_m denotes the regression coefficients for the control variables, μ_f and μ_t are enterprise fixed effects and time fixed effects respectively, and ε_{ikjt} is the random disturbance term. The conditions for testing the mediating effect model are as follows:

(a) The promotion effect of trade facilitation on the export technological complexity of manufacturing enterprises is significant, i.e., the coefficient α_1 in the expected Equation (8) is greater than 0. (b) The promotion effect of the mediating variable on the export technological complexity of manufacturing enterprises is significant, i.e., the coefficient γ_n in the expected Equation (9) is greater than 0. (c) The promotion effect of trade facilitation on the mediating variable is significant, i.e., the coefficient σ_n in the expected Equation (10) is greater than 0. (d) After simultaneously including trade facilitation and the mediating variable, the regression coefficient λ_1 for trade facilitation is no longer significant, or its significance decreases. In other words, the coefficient λ_1 in Equation (11) is smaller than the coefficient α_1 for trade facilitation in Equation (8).

As shown in Table 9, the results of the mediation effect regression are presented. Upon observing the regression results in the first column, it is evident that trade facilitation positively promotes the export technological complexity of manufacturing enterprises, meeting condition (a). Examination of the regression results in the second column reveals that, except for the competition effect, all other intermediary variables significantly impact the export technological complexity of manufacturing enterprises at the 1% level, satisfying condition (b). Analysis of columns three through six indicates that, aside from the technological innovation effect, trade facilitation significantly affects other intermediary variables at the 1% level, meeting condition (c). Observing the results in the seventh column, it is noted that upon including trade facilitation and all intermediary variables, the regression coefficient of trade facilitation significantly decreases and is only significant at the 10% level, fulfilling condition (d).

In summary, trade facilitation can positively promote the export technological complexity of manufacturing enterprises through cost reduction, technological innovation, competition, and enhanced enterprise productivity, thus supporting hypothesis 2.

Table 9. Results of intermediate effect test.

Name of variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CETC	*CETC*	*Cost*	*Input*	*Ics*	*Ltfp*	*CETC*
Tf	0.0751*** (4.71)		0.0425 (−4.78)	0.0273* (2.27)	0.0038*** (4.17)	0.0318*** (4.71)	0.0014* (1.81)
Cost		0.0514 (−3.14)					0.0409 (−4.51)
Input		0.0201*** (5.13)					0.0196*** (3.94)
Ics		0.0051* (1.78)					0.0051* (1.68)
Ltfp		0.0286*** (3.92)					0.0273*** (4.09)
Control variables	Controls	Controls	Controls	Controls	Controls	Controls	Controls
Number of observations	81,850	69,057	74,843	69,057	73,901	81,850	69,057
Corporate fixed effect	yes	yes	yes	yes	yes	yes	yes
Time fixed effect	yes	yes	yes	yes	yes	yes	yes
R^2	0.4192	0.3807	0.3857	0.3582	0.3729	0.3905	0.4208

4) Further Research: Analysis of Trade Facilitation and Regional-Industry Export Technological Complexity

To ensure the completeness of the study, this paper conducts further research on the relationship between trade facilitation and export technological complexity at the regional-industry level.

First, this paper calculates the regional-industry export technological complexity based on the enterprise-level export technological complexity. The specific calculation formula is shown in Equation (12):

$$CETC_{ikt} = \sum_{j \in \Omega_{ik}} \rho_{jt} CETC_{ikjt} \tag{12}$$

In the equation, i represents regions, k represents industries, t represents time, and j represents enterprises. Ω_{ik} denotes the collection of enterprises j belonging to region i and industry k. $CETC_{ikj}$ represents the export technological complexity of region i and industry k. ρ_{it} denotes the aggregation weight, calculated using the proportion of export value of a company in the customs database to the total export value of companies in the region and industry. $CETC_{ijkt}$ represents the export technological complexity at the enterprise level.

Furthermore, this paper draws on the analysis method of Griliches and Regev (1995) to decompose the export technological complexity at the regional-industry level into four components: within-firm effect, between-firm effect, entrants effect and exiters effect. The within-firm effect refers to the impact of changes in export technological complexity at the region-industry level resulting from changes in the export technological complexity of the enterprise itself. The between-firm effect refers to the impact of changes in the export share of enterprises on the export technological complexity at the region-industry level. The entrants effect pertains to the impact of changes in export technological complexity at the region-industry level following the entry of new firms. The exiters effect refers to the impact on export technological complexity at the region-industry level following the exit of enterprises from the market. The combination of between-firm effect, entrants effect and exiters effect is commonly referred to as the resource reallocation effect.

First, calculate the change in export technological complexity at the regional-industry level from period t to period $t-1$, as shown in Equation (13):

$$\Delta CETC_{ikt} = \sum_{j \in (L,M)} \rho_{jt} CETC_{ikjt} - \sum_{j \in (L,N)} \rho_{jt} CETC_{ikjt} \tag{13}$$

Then, further decompose the change in export technological complexity, as shown in Equation (14), where L, M and N represent the sets of existing enterprises, entering enterprises, and exiting enterprises, respectively.

$$\begin{aligned} \Delta CETC_{ikt} = & \underbrace{\sum_{j \in L} \bar{\rho}_j \Delta CETC_{ikjt}}_{\text{within-firm effect}} + \underbrace{\sum_{j \in L} \Delta \rho_{jt} \left(\overline{CETC_j} - CETC_{iM} \right)}_{\text{between-firm effect}} \\ & + \underbrace{\sum_{j \in M} \rho_{jt} \left(CETC_{ikjt} - \overline{CETC_{iM}} \right)}_{\text{entrants effect}} \\ & - \underbrace{\sum_{j \in N} \rho_{jt-i} \left(CETC_{ikjt-1} - \overline{CETC_{iM}} \right)}_{\text{exiters effect}} \end{aligned} \tag{14}$$

where, the underlined variable represents the mean value of the variable. When the export technological complexity of a newly entering enterprise exceeds the average export technological complexity of existing enterprises in the region and industry, it is considered that the entry effect of the enterprise is positive. Similarly, when the export technological complexity of an exiting enterprise falls below the average export technological complexity of enterprises in the region and industry, the exiters effect of the enterprise is considered positive.

To investigate whether the resource reallocation effect is the mechanism for improving export technological complexity at the region-industry level, this paper constructs the following model, as shown in Equation (15):

$$CETC_{ikt} = \alpha_0 + \alpha_1 tf_{ikt} + \delta_m X_{ikt} + \mu_t + \mu_i + \mu_k + \varepsilon_{ikt} \tag{15}$$

In Equation (15), $CETC_{ikjt}$ represents the impact of changes in export technological complexity at the regional-industry level due to resource reallocation effects and its various decomposition components. tf_{ikt} denotes the level of trade facilitation at the regional-industry level, X_{ikt} represents control variables, derived from enterprise-level control variables aggregated by regional-industry. μ_i, μ_t and μ_k respectively denote regional, time, and industry fixed effects, while ε_{ikt} represents the random disturbance term.

The regression results are shown in **Table 10**. The observed results show that the resource reallocation effect is an important way for trade facilitation to promote the improvement of export technological complexity of manufacturing enterprises. The effects of trade facilitation on intra-firm effect, inter-firm effect and firm entry effect of manufacturing enterprises are significantly positive, while the effects on exiters are significantly negative, indicating that trade facilitation is conducive to promoting the exit of enterprises with low technological complexity and the entry of enterprises with high technological complexity, so as to realize the transfer of resources from enterprises with low technological complexity to enterprises with high technological complexity.

Table 10. Test results of resource reallocation effect.

Variable name	Export technological complexity (*CETC*)				
	Resource reallocation effect	Within-firm effect	Between-firm effect	Entrants effect	Exiters effect
tf_{ikt}	0.0106*** (5.03)	0.0048*** (3.92)	0.0069*** (4.28)	0.0081** (2.47)	0.0153 (−1.72)
Control variables	Controls	Controls	Controls	Controls	Controls
Region fixed effect	yes	yes	yes	yes	yes
Time fixed effect	yes	yes	yes	yes	yes
Industry fixed effect	yes	yes	yes	yes	yes
Number of observations	13497	10694	10694	8016	7769
R^2	0.208	0.172	0.179	0.184	0.182

6. Conclusion

This paper delves into the mechanism by which trade facilitation influences the export technological complexity of manufacturing enterprises, focusing specifically on the impact on Chinese manufacturing enterprises. Utilizing matched data from the China Industrial Enterprise Database, Customs Database, and Enterprise Patent Database, the study confirms its research hypothesis through analysis at the enterprise level.

Both the level of trade facilitation and the export technological complexity of manufacturing enterprises are on the rise. However, there is a narrowing gap between enterprises in terms of trade facilitation levels, while the technological complexity of exports is increasing, accompanied by heightened polarization.

Trade facilitation significantly enhances the export technological complexity of China's manufacturing enterprises, with relatively stable results observed. The positive influence of trade facilitation on the export technological complexity of manufacturing enterprises is primarily attributed to the cost reduction effect, technological innovation effect, competition effect, and productivity improvement.

In addition to confirming the previous study hypothesis, further research findings reveal significant heterogeneity in the impact of trade facilitation on the export technological complexity of manufacturing enterprises. This heterogeneity stems from differences in ownership types, factor intensity, and geographical locations of enterprises. The resource reallocation effect emerges as a crucial mechanism through which trade facilitation promotes the enhancement of export technological complexity in manufacturing enterprises. This effect involves the transfer of resources from low-tech complexity enterprises to high-tech complexity enterprises, primarily achieved through the withdrawal of low-tech complexity enterprises and the entry of high-tech complexity enterprises.

Concerned with the development trajectory of an open economy, a key focus should be directed towards assessing the export technological complexity within that economy. Proposals aimed at promoting the high-quality development of the economy should, therefore, prioritize strategies to enhance the technological sophistication of the economy's exports. Drawing from the conclusions, the following suggestions are provided on how open economies can leverage trade facilitation to bolster the technological complexity of their exports.

Enhancing the export technological complexity of manufacturing enterprises can effectively drive the transformation, upgrading, and high-quality development of these enterprises. Given that the development of trade facilitation can effectively promote the export technological complexity of manufacturing enterprises, further advancing national trade facilitation is pivotal in this regard.

Using China as an example, the significant gap between the trade facilitation of its manufacturing enterprises and their export technological complexity highlights regional development imbalances. Therefore, adopting a strategy for balanced regional development can help narrow this gap. Government initiatives should aim at fostering the coordinated development of enterprises across all regions of the country.

Heterogeneity test results indicate varying rates of upgrading in export technological complexity. Hence, alongside improving the level of trade facilitation, efforts should be made to stimulate enterprise reform and innovation to address the disparities in upgrading speeds.

Regression tests on various trade facilitation indicators reveal that port efficiency and the institutional environment play a stronger role in promoting the export technological complexity of manufacturing enterprises. Consequently, the government could prioritize initiatives aimed at enhancing port efficiency and the institutional environment to accelerate the upgrading of export technological complexity in the manufacturing sector.

Declarations

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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