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Research on the Impact of Cross-border E-commerce Development on Export Structure Upgrading

Wenna Wu

School of Economics, Nanjing Audit University, Nanjing, Jiangsu, China

Abstract: ***This study examines how cross-border e-commerce contributes to export structure upgrading using panel data from Chinese cities and a two-way fixed effects model. Export upgrading is measured by the shares of green products and high-tech products in total exports. The results show that cross-border e-commerce significantly promotes both dimensions of upgrading, with the findings remaining robust across alternative specifications and instrumental variable estimation. Mechanism analysis suggests that green technological innovation and improved resource allocation are important channels. Positive effects are statistically significant in cities with greater trade openness and higher intervention. These findings provide empirical support for policies that integrate cross-border e-commerce development with green innovation and technological upgrading.***

Keywords: Cross-border e-commerce, Export structure upgrading, Greening of exports, Upgrading of exports.

1. Introduction

The report of the 20th National Congress of the Communist Party of China clearly proposed to "promote the optimization and upgrading of goods trade, innovate the development mechanism of service trade, develop digital trade, and accelerate the construction of a strong trading nation," pointing the way for the transformation and development of China's foreign trade. In 2024, nine departments, including the Ministry of Commerce, jointly issued the "Opinions on Expanding Cross-border E-commerce Exports and Promoting the Construction of Overseas Warehouses," emphasizing the coordinated development of cross-border e-commerce and new foreign trade infrastructure such as overseas warehouses. This aims to optimize the foreign trade structure and cultivate new advantages in international economic cooperation by reducing intermediate links and directly connecting consumers. With the continuous advancement of the construction of comprehensive cross-border e-commerce pilot zones, and the gradual improvement of supporting systems such as platform operation, logistics and distribution, payment settlement, and customs supervision, cross-border e-commerce has become an important driving force for the development of China's foreign trade. According to customs statistics, in 2025, the total import and export value of China's cross-border e-commerce reached 2.84 trillion yuan, a year-on-year increase of 4.8%, demonstrating the vitality of this new form of foreign trade.

However, increased trade volume does not necessarily equate to an upgraded export structure. While China possesses a strong competitive advantage in exports due to its comprehensive manufacturing system and supporting industrial chains, some export enterprises still face challenges such as low product added value, insufficient competitiveness of their own brands, and limited capacity for green transformation. Under the combined influence of trade protectionism, green trade barriers, and resource and environmental constraints, the traditional growth model relying on low costs and scale expansion faces challenges, making the transformation of exports towards high technology, high added value, and green, low-carbon practices increasingly urgent. Cross-border e-commerce, by reducing market entry and information search costs and shortening the supply-demand feedback chain, provides new conditions for enterprises to conduct product innovation, brand building, and supply chain optimization, thus creating possibilities for upgrading the export structure.

Whether cross-border e- commerce can translate its channel and efficiency advantages into substantial improvements in export structure remains to be seen. On the one hand, digital platforms connect global demand, potentially promoting adjustments in enterprise R&D, design, and production, and driving the upgrading of exports. On the other hand, demand information transmission and supply chain collaboration may support green production and improved resource allocation efficiency, but their effectiveness is also influenced by factors such as enterprise technological capabilities and environmental constraints. Therefore, this paper focuses on the impact of cross-border e-commerce development on export structure upgrading, examining it from two dimensions: export upgrading and export greening. It investigates whether and through what pathways cross-border e-commerce can promote urban export structure upgrading, aiming to provide a reference for improving cross-border e-commerce support policies and promoting the coordinated transformation of foreign trade digitalization and greening.

2. Literature Review

2.1 Research on the Impact of Cross-border E-commerce on Exports

Cross-border e-commerce is a new type of trade that combines digital technology with international trade. Regarding its economic effects, existing research has gradually shifted from macro-level discussions on whether the Internet can promote trade to analysis of how platforms reduce transaction barriers, change enterprise resource constraints, and influence export behavior. Freund and Weinhold's (2002, 2004) research on the Internet's promotion

of service trade and goods trade provided early evidence for understanding the trade effects of digital technology [1] [2]. However, the popularization of the Internet and the development of cross-border e-commerce are not entirely the same concept, and subsequent research has therefore focused more on the specific changes brought about by platform transactions and their supporting systems. This shift in research has made the role of cross-border e-commerce no longer limited to expanding the scale of trade, and has also provided a basis for analyzing the adjustment of export product mix.

Regarding trade costs, relevant literature generally believes that cross-border e-commerce can alleviate information barriers in traditional trade, but it does not eliminate all transaction frictions. Gomez-Herrera et al. (2014) and Lendle et al. (2016) found that e-commerce can reduce the constraints of geographical distance on cross-border transactions, but factors such as language, payment and logistics still affect the realization of transactions [3] [4]. Based on data from Chinese enterprises and platforms, Zhang Hongsheng and Pan Gangjian (2021) and Ju Xuenan et al. (2020) further distinguished trade costs into different stages, emphasizing that cross-border e-commerce has advantages in reducing information search and distribution costs, while its impact on production, transportation and other costs is relatively limited [5]. The former type of research focuses on the changes in distance constraints caused by digital transactions, while the latter type of research clarifies the specific sources of cost reduction. Both of them explain that the core role of cross-border e-commerce is to improve market information and transaction matching, and to create conditions for enterprises to find customers, purchase inputs and enter new markets.

Policy evaluation studies further revealed the connection between the above-mentioned cost mechanisms and export expansion. Ma Shuzhong and Fang Chao (2021) found that cross-border e- commerce industrial policies can promote the export of related products, with information cost reduction and economies of scale being important explanations, and their role is more reflected in the change of the export expansion margin [6]. Ma Shuzhong and Guo Jiwen (2022) linked export growth with the decline in trade costs and the easing of financing constraints from the perspective of the construction of comprehensive pilot zones [7]. Both studies showed that cross-border e-commerce related policies can improve the market participation conditions of enterprises, but the former focuses more on information and market size, while the latter further emphasizes the institutional environment and financing support. It is necessary to distinguish that when enterprises enter more markets or increase the variety of export products, it reflects the marginal expansion of exports; only when the newly added or expanded exports are more concentrated in green products and medium and high-tech products is it consistent with the structural upgrading direction of this paper. Therefore, the evidence of export growth provides a premise for studying structural changes, but it cannot directly replace the test of the upgrading results.

Regarding innovation and resource constraints, Zhou Jishun and Zhang Ruonan (2024) and Fu Xiaodie and Liu Yongwen (2025) both emphasized that the cross-border e-commerce pilot zone policy can support enterprise innovation by alleviating financing constraints [8] [9]. This research line extends the role of policy from the transaction link to the production and R&D link, complementing the research on trade costs: improved transaction conditions enable enterprises to obtain more market opportunities, and the easing of financing constraints may improve their ability to utilize these opportunities. However, increased innovation activities do not automatically correspond to an increase in the export share of specific products. The result also depends on the direction of innovation, commercialization capabilities, and the original product structure of enterprises. For the upgrading of exports, the key is whether innovation can support products with higher technological content to enter the international market; for the greening of exports, it is necessary to further examine whether resources are allocated to the production of green technologies and green products. Therefore, the literature on financing and innovation helps to construct the mechanism of action, but it still needs to be linked with specific export structure indicators.

Overall, basic research on the impact of cross-border e-commerce on exports forms a progressively deeper explanatory framework, ranging from reducing transaction barriers and improving resource access to expanding markets and promoting innovation. These studies are not simply repetitive but each has its own focus, specifically addressing whether enterprises can participate in trade, access innovation resources, and adjust production and export decisions. At the same time, the effects of cross-border e-commerce are clearly conditional. On the one hand, the decrease in information costs does not completely eliminate barriers at the logistical, institutional, and market levels; on the other hand, increased market entry opportunities do not necessarily mean that all enterprises possess equal upgrading capabilities. Therefore, when assessing the development effects of cross-border e-commerce, it is necessary to broaden the research perspective beyond export volume and market scope to include the composition of export products, examining whether it has altered the relative position of green products and medium-to-high-tech products in exports.

2.2 Research on the Connotation and Measurement of Export Structure Upgrading

Upgrading of export structure is an important dimension for measuring the quality of trade development. Its connotation has gradually expanded from changes in export categories to improvements in technology level, product quality and environmental attributes. Early studies on China’s export structure revealed the importance of the measurement perspective. Rodrik (2006) emphasized that China’s export products exhibit high technological complexity, while Schott (2008) pointed out through a comparison of product structure and unit value that similar product categories do not necessarily mean that the quality and competitiveness are exactly the same [10] [11]. Chen Xiaohua et al. (2011) further indicated that the judgment on the technological complexity of China’s exports may change after considering factors such as processing trade [12]. The common implication of these studies is that the surface technological characteristics reflected by export scale or product category should not be

directly equated with the local technological capabilities and value creation level; when studying the upgrading of export structure, the objects depicted by the indicators and their explanatory boundaries should be clearly defined.

In terms of technology, the export technology complexity index constructed by Hausmann et al. (2007) provides an analytical tool for measuring the export technology level of a country or region based on the export product mix [13]. Subsequently, related literature has widely used technology complexity to discuss industrial and trade upgrading. In terms of quality, Khandelwal (2010) and Shi Bingzhan and Shao Wenbo (2014) measure export quality from the perspective of market demand and micro-product differences, focusing on the differences in quality levels of similar products [14]. Both technology complexity and product quality can reflect changes in export competitiveness, but the two are not completely overlapping: traditional products can achieve quality improvement through design, process and quality improvement, but may not necessarily transform into products of higher technology categories; products of the same technology category may also have large quality differences. Therefore, related indicators should be regarded as complementary research perspectives, rather than being interchangeable in literature argumentation and empirical interpretation.

As environmental sustainability has gained attention, research on export upgrading has further incorporated the green dimension. Zhou et al. (2023) started from the relationship between green credit and export green complexity, emphasizing the impact of financing conditions and innovation incentives on green exports [15]; Li et al. (2023) started from the relationship between green trade barriers and corporate environmental governance, reflecting the role of external environmental requirements in corporate behavior adjustment [16]. The two types of research focus on financial support and environmental constraints respectively, providing different explanations for understanding green transformation, but green complexity, corporate environmental performance and green product export share each have their own emphasis. The reduction of corporate pollution emissions may be due to the improvement of the original product production process, and does not necessarily lead to an increase in the proportion of green product exports. Therefore, incorporating green development into export structure research requires further clarification on whether the research focuses on the improvement of production methods or the shift of export product mix towards green products.

Wei Ping, Liu Hongman and Xu Chaokai (2025) divided the upgrading of export product structure into export greening and export upgrading from the dual perspectives of environmental and economic sustainability, providing a measurement framework directly corresponding to the research objectives of this paper [17]. Among them, export greening is measured by the proportion of green product export value to the total export value of enterprises, and green products are identified by the CLEG environmental product list; export upgrading is based on Lall's (2000) technology classification, dividing products into high-tech product group and low-tech product group, and is measured by the proportion of high-tech product group export value to the total export value of enterprises [18]. Its high-tech product group includes medium-tech and high-tech products, and low-tech product group includes primary products, resource-based products and low-tech products.

Regarding the impact mechanism, Wei Ping et al. (2025) found that enterprises implementing ESG strategies can generally promote the greening and upgrading of exports through green technology innovation, and its impact will also be transmitted along the supply chain [17]. Further analysis shows that the entry and exit of export products are important manifestations of structural adjustment, and upgrading does not only depend on the increase in the scale of exports of existing products. However, the study also found that for some processing trade enterprises, cost-competitive enterprises and enterprises in high-pollution industries, environmental investment may squeeze out innovation investment, resulting in greening improvement but hindering upgrading. This finding shows that environmental goals and technology upgrading goals may complement each other, or they may be traded off under resource constraints. Therefore, the significance of adopting a two-dimensional framework is not only to add an indicator, but also to avoid directly understanding the improvement of a certain dimension as a comprehensive upgrade of the export structure.

2.3 Research on the Impact of Cross-border E-commerce on Export Structure Upgrading

Regarding the upgrading of exports, the existing direct evidence mainly focuses on the technological complexity of exports. Zhang Hongsheng et al. (2024) and Liu Shanshan and Gao Jiangang (2024) both took the construction of cross-border e-commerce pilot zones as their starting point and found that relevant policies can increase the technological complexity of urban exports. The two studies echo each other in their explanation of technological innovation, but their focus on the mechanism is different: Zhang Hongsheng et al. (2024) emphasizes both industrial structure upgrading and the agglomeration of productive service industries [19], while Liu Shanshan and Gao Jiangang (2024) pay more attention to the improvement of the business environment [20]. The former reflects the supporting role of industrial supporting and professional services, while the latter reflects the influence of institutional conditions on corporate decision-making. These studies suggest that the impact of cross-border e-commerce on technological upgrading may go beyond online transactions themselves and be related to changes in the urban industrial base and innovation environment. However, there is still a difference in the measurement between the increase in technological complexity and the increase in the export share of medium and high-tech products. The relevant results need to be further tested under the product classification caliber used in this paper.

Corresponding to the above-mentioned promotional effects, some studies emphasize the impact of external constraints. Zhu Yongming and Zhang Yu (2022) found that tariff barriers would inhibit the promotion of cross-border e-commerce on the technological complexity of manufacturing exports [21]. This does not necessarily negate the positive effects of the comprehensive pilot zone policy, but rather shows that while digitalization reduces information costs, enterprises still need

to face constraints of international market access and transaction costs. Since different studies use different levels of analysis, sample scopes and policy backgrounds, they cannot be regarded as contradictory conclusions based solely on the strength of the effect. A more reasonable understanding is that cross-border e-commerce provides opportunities for technological upgrading, while institutional, industrial and external market conditions jointly affect whether opportunities can be transformed into actual results. This also provides a basis for subsequent examination of the differences in upgrading under different city conditions.

Product quality research supplements the micro-process of how cross-border e-commerce affects export upgrading. Some scholars have found that cross-border e-commerce policies or platform applications help improve the quality of export products, but their explanations of the process differ. Wei Yueling and Zhang Hongsheng (2022) mainly emphasized that cross-border e-commerce reduces import search costs and improves the quality of intermediate goods, reflecting the input channel [22]; Pan Tong et al. (2024) also focused on the relief of financing constraints, intermediate goods search and innovation capabilities, indicating that there is a connection between resource acquisition and production capacity [23]; Wang and Zhou (2025) highlighted the platform network effect and its role in promoting export quality [24]. Combining these studies, it can be seen that quality upgrading not only comes from the matching of export customers, but may also come from the improvement of import inputs and the enhancement of enterprise internal capabilities.

The aforementioned quality studies and technology complexity studies provide complementary evidence. The former is closer to the micro-level decisions firms make to improve their products, while the latter focuses more on changes in the composition of export technologies in a region or industry. However, improvements in product quality do not necessarily lead to changes in product technology categories, and increased technology complexity does not necessarily mean that all firms' product quality improves simultaneously. Furthermore, market demand information brought about by cross-border e-commerce may both drive improvements to existing products and guide firms to develop new products.

Regarding the greening of exports, relevant literature provides more indirect evidence on green innovation and low-carbon transformation. Jiang Jinhe and Huang Shan (2024) used the cross-border e-commerce pilot zone policy as a quasi-natural experiment and adopted a dual machine learning method to find that the policy can significantly improve the level of urban green technology innovation and show a green innovation bias [25]. Its channels of action include improving the green management capabilities of local enterprises, stimulating the entrepreneurial activity of green industries, and strengthening intellectual property protection. This study extends the impact of cross-border e-commerce from general innovation to innovation direction, and is therefore closer to the mechanism of export greening than studies that only examine the quantity of innovation.

Wei Bin (2024) studied the impact of low-carbon economic transformation on the export quality of cross-border e-commerce enterprises, emphasizing the role of green technology innovation in this process [26]. This study, like Jiang Jinhe and Huang Shan (2024), focuses on green innovation [25], but their causal directions and explanatory objects are different: the former discusses how low-carbon transformation affects the export quality of specific enterprises, while the latter discusses how cross-border e-commerce policies affect urban green innovation.

2.4 Literature Review

In summary, existing research has provided relatively comprehensive explanations for the impact of cross-border e-commerce on exports from the perspectives of trade costs, financing constraints, technological innovation, and the institutional environment. Regarding export upgrading, research on technological complexity and product quality provides substantial direct evidence, while research on green innovation and low-carbon transformation expands the environmental dimension. The value of different studies lies in revealing the stages of trade, production, innovation, and product adjustment, rather than simply providing repetitive proof of the same conclusion. However, since export scale, product quality, technological complexity, green innovation, and the share of green products correspond to different concepts, the connections between the literature need to be established on the basis of clearly defined measurement boundaries to avoid collectively referring to related economic effects as export structure upgrading.

Building upon existing research, three aspects warrant further investigation. First, in terms of outcome measurement, it is necessary to directly focus on the export product mix, incorporating greening and upgrading into a unified analytical framework to differentiate between the quantitative growth and structural changes brought about by cross-border e-commerce. Second, regarding effect comparison, existing studies often discuss technological upgrading or green development separately. Whether cross-border e-commerce can simultaneously address both objectives, and whether differences arise due to varying resource conditions, requires further examination. Third, in terms of mechanism explanation, declining trade costs, improved financing, and increased innovation offer possible pathways, but whether these intermediate changes can ultimately translate into adjustments in urban export share needs verification based on specific results. Furthermore, quality or ESG research at the firm level cannot be directly extrapolated to policy effects at the city level; the connection between research levels still requires careful handling.

Based on this, this paper draws on the measurement approach of Wei Ping et al. (2025) and uses the export share of green products and the export share of high-tech products to characterize the greening and upgrading of urban exports [17], and examines the impact of cross-border e-commerce development on the two types of structural changes. In the mechanism discussion, combined with relevant research on information and transaction costs, financing constraints and technological innovation, this paper analyzes how cross-border e-commerce changes the export choices of enterprises and the composition of urban export products; in the interpretation of the results, this paper focuses on the

commonalities and differences of the two types of upgrading effects, without presuming that greening and upgrading must be synchronized. This paper connects the relatively scattered technological upgrading and green transformation clues in the existing research, and provides supplementary evidence for understanding the relationship between the development of cross-border e-commerce and the sustainable upgrading of exports.

3. Methodologies

3.1 The Direct Effect of Cross-border e-commerce Development on Export Structure Upgrading

The transaction cost theory holds that the information search, business negotiation, contract performance and cross-border delivery links in traditional international trade constitute high transaction costs, forming an implicit barrier for enterprises, especially small and medium-sized enterprises, to participate in foreign trade. Cross-border e-commerce relies on digital transaction platforms to migrate trade links online, and through technologies such as algorithm matching, electronic contracts, online payment and intelligent customs clearance, it significantly reduces information search costs, negotiation costs and performance costs [5] [27]. Lendle et al. (2016) found, based on eBay cross-border transaction data, that cross-border e-commerce reduces the barrier effect of geographical distance on trade by about 65% compared with traditional trade, and this cost reduction has obvious characteristics of inclusive trade. The reduction of the fixed cost threshold for exports enables more small and medium-sized enterprises to break through the scale constraints and enter the international market, thus expanding the export margin [4]. In terms of export upgrading, the reduction of the fixed cost threshold makes the export of small-batch, high-value-added high-tech products economically feasible, and the export potential of high-tech products in the long tail market is activated; cross-border e-commerce also expands the search range of intermediate goods for enterprises and improves the quality of imported intermediate goods, providing input support for the improvement of the quality and technology content of exported products [22]. In terms of export greening, green products, as an emerging category, face higher demand search costs and standard certification costs. Cross-border e-commerce reduces the supply and demand matching costs of green products and the information acquisition costs of international green standards, thus opening up market space for green product exports.

Endogenous growth theory emphasizes that the expansion of market size can increase the expected returns of innovation activities. Cross-border e-commerce breaks through geographical boundaries and connects local enterprises to the global consumer market, effectively expanding the potential market size faced by enterprises: on the one hand, market expansion dilutes the fixed costs of R&D innovation, increases the returns on innovation, and incentivizes enterprises to increase R&D investment [6]; on the other hand, the entry of more market players intensifies international market competition, forcing enterprises to maintain their competitive advantage through technological upgrading and product iteration [28]. Empirical evidence shows that the development of cross-border e-commerce has significantly increased the technological complexity of urban exports [19] and promoted the upgrading of export product quality by promoting enterprise innovation [23] [31]. The innovation incentives and competitive pressures caused by market expansion jointly promote the iterative upgrading of urban export products towards high technology and green low carbon.

At the same time, the massive transaction data accumulated by cross-border e-commerce platforms has alleviated information asymmetry in international trade, enabling enterprises to identify demand signals in the international market at low cost and with precision [6]. With the rise of global green consumption and the tightening of environmental standards in various countries, the international market's demand preference for green products and willingness to pay for high-tech products are directly transmitted to the production end through the platform, forming a demand-driven innovation mechanism that guides production resources to be allocated to technology-intensive and environmentally friendly fields. The research by Wei Ping et al. (2025) shows that in target markets with higher environmental standards, enterprises face greater pressure from green demand and have a stronger motivation to transform their export product structure towards green and advanced products [17]. Thus, the precise transmission of demand signals provides a continuous driving force from the market for the upgrading of export structure.

Based on the analysis of transaction cost theory and endogenous growth theory, the study proposes the following hypothesis:

H1a: The development of cross-border e-commerce can improve the greening level of urban exports.

H1b: The development of cross-border e-commerce can enhance the sophistication of urban exports.

3.2 Intermediary Mechanisms for Green Technology Innovation

Green technology innovation has the dual externalities of knowledge spillover and environmental improvement. Its effective occurrence depends on four conditions: the appropriability of innovation benefits, market demand, moderate competitive pressure, and professional service support. [29] [30] [31] Cross-border e-commerce has created conditions for green technology innovation in the above four aspects: First, the real-name authentication, credit evaluation and intellectual property governance rules established by the platform have strengthened the governance of counterfeit and shoddy goods, and ensured the appropriability of green innovation benefits. [8] Second, cross-border e- commerce breaks through geographical boundaries, enabling enterprises to directly connect with global green consumption demand, and amplifying the demand-driven effect of green innovation. [17] Third, the reduction of market access threshold has intensified export competition, and green barriers constitute de facto regulatory pressure. The superposition of competition and regulation forms a reverse-forcing mechanism for green innovation. [16] [32] Fourth, cross-border e-commerce has

driven the integration of productive services such as digital marketing, inspection and testing, and supply chain finance into the export process, providing factor support for green innovation. Empirical studies have confirmed that the development of new trade formats such as cross-border e-commerce comprehensive pilot zones has significantly promoted urban green technology innovation [25].

Green technology innovation is the core driving force for the green transformation of exports [17]. It is transformed into a practical improvement in the greening of exports through three paths: First, green technology innovation promotes enterprises to update production equipment and processes, reduce energy consumption and pollution emissions in the production process of export products, and enable existing products to meet international green standards; Second, green technology innovation directly creates environmentally friendly new products, enriches the supply of green products in cities, improves the quality and environmental performance of green products, and enhances the competitiveness and recognition of green products in the international market [26]; Third, after green technology matures, it spreads to the upstream and downstream of the industrial chain, driving the overall green transformation of related industries. The above effects together increase the proportion of green product exports in the city's total exports and realize the green upgrading of the export structure.

Based on the analysis of technology spillover theory and Porter's hypothesis, the study proposes the following hypothesis:

H2: The development of cross-border e-commerce can improve the greening level of urban exports by promoting urban green technology innovation.

3.3 Mediating Mechanisms for Resource Allocation

Under the traditional trade model, the effective allocation of factors is highly dependent on geographical proximity. Industrial agglomeration is the main organizational way for traditional business formats to obtain allocation efficiency. However, spatial agglomeration is accompanied by rising land and labor costs and congestion effects, and its coverage is also limited by geographical radius. The core advantage of cross-border e-commerce lies in breaking spatial restrictions. The matching mechanism of digital platforms enables geographically dispersed enterprises, factors and market demands to connect at low cost. The allocation radius is expanded from geographical space to digital space. Even if industries are dispersed in space, cross-border e-commerce can still play its allocation and matching advantages. The theory of division of labor shows that the expansion of market scope and the improvement of transaction efficiency are the fundamental driving forces for the deepening of division of labor [33]. The systematic reduction of search, negotiation and performance costs by cross-border e-commerce is the leap in transaction efficiency, making it possible for factor matching and professional cooperation among dispersed entities on a larger scale.

The theory of heterogeneous enterprise trade further points out that the decline in trade costs will lead to the reallocation of resources from low-productivity enterprises to high-productivity enterprises [34]. The reduction in market access thresholds and information friction brought about by cross-border e-commerce will, on the one hand, intensify market competition and cause inefficient and backward production capacity to gradually exit the market; on the other hand, it will cause high-quality production factors such as capital, labor, and technology to continue to concentrate on high-productivity export enterprises, forming a dynamic adjustment process of survival of the fittest and optimal allocation. Empirical studies have shown that improved factor allocation can significantly increase the technological complexity of exports [35], and the development of cross-border e-commerce has significantly improved the total factor productivity of export enterprises [36] and the technological complexity of urban exports [19]. The continuous concentration of resources in high-productivity and high-tech sectors has increased the overall technological complexity and R&D density of urban export products, and promoted the transformation of export structure towards a more advanced direction.

Based on the analysis of the theory of specialization of labor and the theory of trade by heterogeneous firms, the study proposes the following hypotheses:

H3: The development of cross-border e-commerce can improve the sophistication of urban exports by optimizing resource allocation.

4. Research Design

4.1 Model Setting

To examine the impact of cross-border e-commerce development on the city's export structure, this paper sets up the following benchmark regression model:

$$Green_{i,t} = \alpha_0 + \alpha_1 CBEC_{i,t} + \sum \beta_k Control_{i,t} + \mu_i + \theta_t + \varepsilon_{i,t} \quad (1)$$

$$Sophistication_{i,t} = \alpha_0 + \alpha_1 CBEC_{i,t} + \sum \beta_k Control_{i,t} + \mu_i + \theta_t + \varepsilon_{i,t} \quad (2)$$

Where i and t represent city and year, respectively; the explained variable $Green_{i,t}$ is the level of greening of exports of $Sophistication_{i,t}$ city i in year t, *and the level of upgrading of exports* of city i in year t; the core explanatory variable $CBEC_{i,t}$ is the level of cross-border e-commerce development of $Control_{i,t}$ city i in year t; represents a series of control variables that may affect the upgrading of export structure; the model also incorporates city fixed effects μ_i and year fixed effects θ_t to mitigate the impact of unobservable city characteristics and macro time trends on the estimation results; $\varepsilon_{i,t}$ represents the random disturbance term.

the mechanism of green technology innovation and resource allocation efficiency in the impact of cross-border e-commerce on export structure upgrading, this paper adopts the suggestion of Jiang Ting (2022) [37] and uses a two-step method to test the mediation effect, constructing the following model:

$$GTI_{i,t}/RE_{i,t} = \lambda_0 + \lambda_1 CBEC_{i,t} + \sum \delta_k Control_{i,t} + \mu_i + \theta_t + \varepsilon_{i,t} \quad (3)$$

Wherein, $GTI_{i,t}$ represents the level of green technology innovation of city i in year t; $RE_{i,t}$ represents the resource allocation of city i in year t; and the meanings of the other variables are the same as those in equation (1).

4.2 Variable Description

4.2.1 Explained Variable.

This paper describes the upgrading of urban export structure from two dimensions: export greening and export sophistication. The two dimensions reflect the optimization direction of export structure from the perspectives of environmental attributes and technological attributes, respectively. (1) Export greening is measured by the proportion of urban green product exports to total urban exports. Green products are defined according to the National Bureau of Statistics' "Statistical Product Classification Catalog" and the classification standards for energy conservation and environmental protection industries, covering three major areas: energy conservation and environmental protection, clean production and clean energy. Specifically, they include clean energy equipment and high-efficiency energy-saving products such as electric passenger vehicles, lithium batteries, solar cells, and wind turbine generators. The larger the value of this indicator, the higher the level of export greening. (2) Export sophistication is measured by the proportion of urban high-tech product exports to total urban exports. High-tech products are defined according to the OECD and World Bank's common standards, based on the intensity of R&D investment. Specifically, they cover high R&D density fields such as aerospace, computer and office equipment, electronic communication, pharmaceutical manufacturing, and scientific instruments. The larger the value of this indicator, the higher the level of export sophistication.

4.2.2 Explanatory variables.

Cross-border e-commerce development level (*CBEC*). Since there is no unified indicator for measuring the development level of cross-border e-commerce at the city level, this paper draws on the idea of Zhang Xiaoyan (2023) [38] and constructs a comprehensive evaluation index system from the two dimensions of development strength and development potential. After objectively weighting each indicator using the entropy method, the comprehensive index of cross-border e-commerce development in the city is obtained. As shown in Table 1, the development strength dimension includes four indicators: e-commerce transaction volume, number of employees in the tertiary industry, per capita regional GDP and total retail sales of consumer goods. The development potential dimension includes four indicators: number of international Internet users, number of cross-border e-commerce enterprises, number of mobile phone users at the end of the year and cross-border express delivery volume. These indicators reflect the potential development space of cross-border e-commerce in the city from four perspectives: digital infrastructure, market activity, mobile terminal penetration level and cross-border logistics service capabilities.

Table 1: Indicator System for the Development Level of Cross-border E-commerce in Cities

Variable	Dimension	Index	Property
Cross-border e-commerce development level	Development strength	E-commerce transaction volume	just
		Employment in the tertiary sector	just
		per capita GDP	just
		Total retail sales of consumer goods	just
	Development potential	Number of international Internet users	just
		Number of cross-border e-commerce enterprises	just
		Mobile phone user numbers at the end of the year	just
		Cross-border logistics service capabilities	just

4.2.3 Mediating variables.

(1) Green technology innovation (*GTI*) is measured by the number of green patent applications in cities (unit: 10,000) and reflects the level of innovation output in the field of green technology. The definition of green patents refers to the classification standard of the "List of Green Patents" issued by the World Intellectual Property Organization (WIPO), which covers green technology fields such as alternative energy production, energy conservation in transportation, energy conservation in buildings and waste treatment. (2) Resource allocation (*RE*) uses the total factor productivity of cities as a proxy variable. The fixed effects model (FE) is used to calculate the output elasticity of capital and labor based on the Cobb-Douglas production function, and the residual term after deducting factor contributions from actual output is used to calculate the total factor productivity level of each city over the years. Among them, output is the actual regional GDP after price deflator, capital stock is calculated using the perpetual inventory method with a depreciation rate of 9.6%, and labor input is the total number of employed persons in the whole society (Tian Youchun et al., 2017) [39].

4.2.4 Control variables.

To eliminate interference from other factors, based on the research of Zhang Xiaoyan (2023) [38], Yue Wen and Zhang Jinbo (2026) [40], this paper selects the following control variables: economic development level (*pgdp*), measured by the natural logarithm of per capita GDP of the city; financial development level (*fin*), measured by the ratio of deposit balance of financial institutions to GDP of the city; openness level (*open*), measured by the ratio of total import and export volume of the city to GDP; human capital level (*hum*), measured by the natural logarithm of the number of students enrolled in ordinary colleges and universities in the city; industrial structure (*ind)*, measured by the proportion of added value of the tertiary industry to GDP of the city; fiscal revenue and expenditure pressure (*fis*), measured by the proportion of the difference between local government general budget expenditure and revenue to GDP of the city; degree of government intervention (*gov*), measured by the proportion of local government general budget expenditure to GDP of the region; mobile phone penetration rate (*mobile*), measured by the ratio of the number of mobile phone users at the end of the

year to the registered population.

4.3 Data Description and Descriptive Statistical Analysis

This paper selects panel data of prefecture-level and above cities in China from 2015 to 2024 as the research sample. To ensure the scientific validity and effectiveness of the data for empirical estimation, this paper excludes city samples with severely missing key variables. The data mainly comes from the *China Urban Statistical Yearbook*, *China Statistical Yearbook*, *China E-commerce Yearbook*, and the State Intellectual Property Office Patent Database. Descriptive statistics of the core variables are shown in Table 2. Among them, the mean of export greening is 0.105, and the mean of export upgrading is 0.145, indicating that the proportion of green products and high-tech products in the city's export structure was generally low during the sample period, and there is still considerable room for improvement in export structure upgrading. The mean of the cross-border e-commerce development level is 0.026, the standard deviation is 0.045, and the maximum value is 0.958, reflecting the large differences in the development level of cross-border e-commerce among different cities, showing an uneven distribution. The distribution of the remaining control variables is within a reasonable range.

Table 2: Descriptive Statistics of Variables

	Variable	Symbol	Sample size	Mean	Standard deviation	Minimum value	Maximum value
Explained variable	Greening exports	*Green*	2337	0.105	0.050	0.010	0.328
	Export upgrading	*Sophistication*	2337	0.145	0.067	0.020	0.498
Explanatory variables	Cross-border e-commerce development level	*CBEC*	2337	0.026	0.045	0.002	0.958
Mediator variables	Green technology innovation	*GTI*	2337	0.110	0.269	0.000	3.452
	Resource allocation	*RE*	2337	1.284	0.412	0.210	2.665
Control variables	Economic development level	*pgdp*	2337	10.98 1	0.479	9.729	12.34
	Level of openness to the outside world	*open*	2337	0.177	0.243	0.001	2.712
	Industrial structure	*ind*	2337	0.481	0.080	0.224	0.853
	Financial development level	*fin*	2337	1.704	0.745	0.571	20.10
	Human capital level	*hum*	2337	0.020	0.019	0.001	0.123
	Fiscal revenue and expenditure pressure	*fis*	2337	0.124	0.0890	-0.009	0.627
	Degree of government intervention	*gov*	2337	0.200	0.087	0.0590	0.694
	Mobile phone penetration rate	*mobile*	2337	1.147	0.675	0.423	9.010

5. Discussion

5.1 Benchmark Analysis Results

Table 3 reports the baseline regression results of cross-border e-commerce development on urban export greening and export sophistication. Columns (1) and (3) did not include control variables, while columns (2) and (4) included both control variables and two-way fixed effects for city and year. Regarding export greening, column (1) shows an estimated coefficient of 0.047 for the level of cross-border e-commerce development, which is significantly positive at the 5% level, indicating that cities with higher levels of cross-border e-commerce development have correspondingly higher levels of export greening. After adding all control variables in column (2), the estimated coefficient of the core explanatory variable remains significantly positive, and its promoting effect remains robust. Economically, for every unit increase in the level of cross-border e-commerce development, the level of urban export greening increases by approximately 0.046 units. Regarding export sophistication, column (3) shows an estimated coefficient of 0.055 for the level of cross-border e-commerce development, which is significant at the 5% level. After adding all control variables in column (4), the estimated coefficient is significantly positive, indicating that cross-border e-commerce development significantly promotes the improvement of urban export sophistication. From an economic perspective, for every unit increase in the development level of cross-border e-commerce, the level of sophistication of urban exports increases by approximately 0.049 units. These results indicate that the development of cross-border e-commerce not only directly promotes the green transformation of export products but also facilitates their upgrading towards higher technology content, thus verifying research hypotheses H1a and H1b.

Table 3: Benchmark Regression Results

Variable	(1) *Green*	(2) *Green*	(3) *Sophistication*	(4) *Sophistication*
CBEC	0.047 **	0.046 ***	0.055 **	0.049 **
	(0.022)	(0.017)	(0.022)	(0.021)
pgdp		-0.015		0.001
		(0.010)		(0.013)
open		0.008		-0.002
		（0.013）		(0.010)
in		-0.041		-0.049
		（0.029）		（0.035）
fine		0.003 ***		-0.003 ***
		(0.001)		(0.001)
hum		0.243		-0.168
		（0.166）		（0.179）
fart		0.100		0.101
		（0.077）		（0.117）
government		-0.097		-0.043
		（0.065）		（0.102）
mobile		-0.009 *		-0.003
		(0.005)		(0.006)
constant term	0.104 ***	0.292 **	0.143 ***	0.163
	(0.001)	(0.122)	(0.001)	(0.154)
Year fixed effect	yes	yes	yes	yes
Urban fixed effects	yes	yes	yes	yes
Sample size	2337	2337	2337	2337
Adjust *R2*	0.574	0.576	0.604	0.604

Note: The values in parentheses are the robust standard errors of the city-level clustering. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Unless otherwise specified, the same applies below.

5.2 Robustness Test

5.2.1 Replace the explained variable

Considering that the measurement method of the core variables may affect the regression results, this paper tests the robustness of the baseline results by replacing the dependent variables. In the baseline regression, export greening and export sophistication are measured by relative values. In this paper, the two dependent variables are replaced by green product export value (*Green 1*) and high-tech product export value (*Sophistication 1*), respectively, and the absolute level of export scale is used to measure them. The model is then re-estimated. The results are shown in columns (1) and (2) of Table 4. After replacing the dependent variables, the estimated coefficients of cross-border e-commerce development on export greening and export sophistication are significantly positive at the 1% level, consistent with the baseline regression results, providing evidence for the robustness of the results in this paper.

Table 4: Robustness test results

Variable	Replace the explained variable		Excluding special years	
	Green 1	*Sophistication* 1	*Green*	*Sophistication*
	(1)	(2)	(3)	(4)
CBEC	6.774 ***	10.511 ***	0.047 ***	0.075 ***
	(0.893)	(0.694)	(0.015)	(0.023)
control variables	yes	yes	yes	yes
Year fixed effect	yes	yes	yes	yes
Urban fixed effects	yes	yes	yes	yes
Sample size	2337	2337	1403	1403
Adjust *R2*	0.850	0.906	0.568	0.599

5.2.2 Exclude special years

During the COVID-19 pandemic from 2020 to 2022, the global supply chain was significantly impacted, international trade activities fluctuated markedly, and the export product structure may have been affected by exogenous shocks, thus affecting the accurate identification of the effects of cross-border e-commerce development. To ensure the robustness of the conclusions, this paper removed the sample data during the pandemic and re-estimated the results, as shown in columns (3) and (4) of Table 4. It can be found that, after excluding the impact of the pandemic, the estimated coefficients of cross-border e-commerce development on export greening and export upgrading are still significantly positive at the 1% level, indicating that the promoting effect of cross-border e-commerce on export structure upgrading remains robust.

5.2.3 Discussion of Endogeneity Issues

There may be a two-way causal relationship between the development of cross-border e-commerce and the upgrading of urban export structures. The development of cross-border e-commerce promotes the greening and sophistication of exports; however, cities with more optimized export structures may have better industrial foundations and institutional environments, which in turn attract the agglomeration of cross-border e-commerce industries and promote the development of cross-border e-commerce. To mitigate the interference of the aforementioned endogeneity issues on the estimation results, this paper uses the instrumental variable method to handle endogeneity.

This paper selects the average level of cross-border e-commerce development in other cities within the same province in the same year as the instrumental variable for urban cross-border e-commerce development. Cities within the same province typically face similar provincial policy environments, geographical locations, and infrastructure endowments, exhibiting strong spatial correlation and demonstration effects in cross-border e-commerce development, thus satisfying the relevance requirement of the instrumental variable. Export structure upgrading is mainly driven by factors such as local industrial base, enterprise capabilities, and market demand; the development of cross-border e-commerce in other cities will not directly affect the local export product structure, thus satisfying the exogeneity requirement of the instrumental variable. Table 5 reports the results of the two-stage least squares (2SLS) regression. In the first stage regression, the coefficient of the instrumental variable is significantly positive, indicating a strong correlation with cross-border e-commerce development. *The Cragg-Donald Wald F* statistic is 119.982, which is greater than the 10% critical value for *Stock- Yogo, excluding the problem of weak instrumental variables. Kleibergen-Paap The p-value of the rk LM* statistic is less than 0.01, strongly rejecting the hypothesis of insufficient instrumental variable identification. In columns (2) and (3) of Table 5, the coefficients of CBEC are significantly positive, indicating that after considering the endogeneity issue, the development of cross-border e-commerce still has a significant positive effect on the greening and upgrading of exports, and there is no significant difference from the baseline regression results.

Table 5: Instrumental variable regression results

Variable	(1) Phase 1	(2) Phase Two	(3) Phase Two
	Green	*Green*	*Sophistication*
iv	0.542 ***		
	(0.136)		
CBEC		1.839 **	1.611 *
		(0.744)	(0.958)
Kleibergen-Paap rk LM statistic	14.565 ***		
	[0.000]		
Cragg-Donald Wald F statistic	119.982 ***		
	[16.38]		
Control variables	yes	yes	yes
Year fixed effect	yes	yes	yes
Urban fixed effects	yes	yes	yes
Sample size	2337	2337	2337

5.3 Mechanism Testing

5.3.1 Intermediary mechanisms for green technology innovation

Table 6, column (1) reports the regression results of cross-border e-commerce on green technology innovation. The coefficient of the core explanatory variable is 1.372 and is significant at the 1% level, indicating that cross-border e-commerce significantly promotes the growth of urban green patent applications. Cross-border e-commerce optimizes the innovation ecosystem in all aspects by reshaping intellectual property protection, directly connecting with global green demand, strengthening competition and regulatory pressure, and gathering productive services, thereby significantly stimulating the potential of urban green technology innovation. In addition, green technology innovation mainly promotes the greening of exports through three paths: first, it promotes the green transformation of enterprise production processes, reduces energy consumption and emissions to meet

international green standards; second, it directly fosters environmentally friendly new products, enriches green supply and enhances international market competitiveness [41]; third, it relies on the technology spillover from the upstream and downstream of the industrial chain to drive the overall green transformation of related industries. In summary, cross-border e-commerce effectively improves the export capacity and greening level of green products by incentivizing green technology innovation, and the research hypothesis H2 is verified.

5.3.2 Mediating Mechanisms for Resource Allocation

Column 6 (2) reports the regression results of cross-border e-commerce on resource allocation. The coefficient of the core explanatory variable is significantly positive at the 1% level (0.288), indicating that cross-border e-commerce significantly improves the total factor productivity of the city. Cross-border e-commerce breaks the constraints of physical space, reduces transaction costs by relying on the low-cost matching of digital platforms, and effectively expands the radius of factor flow and resource allocation. At the same time, the continuous agglomeration of resources in high-productivity and high-tech sectors directly improves the overall technical complexity and R&D density of export products; and the improvement of resource allocation efficiency means that unit factor input can be transformed into output with higher technical content, enabling the city to optimize the industrial base of high-tech product exports while maintaining cost advantages. This conclusion is also consistent with existing empirical research [35]. In summary, cross-border e-commerce drives the export of high-tech products by optimizing factor allocation efficiency, thereby promoting the upgrading of the export structure, and the research hypothesis H3 is verified.

Table 6: Mechanism Test Results

variable	(1) *GTI*	(2) *RE*
CBEC	1.3 7 2 ***	0.288 ***
	(0.504)	(0.095)
Control variables	yes	yes
Year fixed effect	yes	yes
Urban fixed effects	yes	yes
Sample size	2337	2337
Adjust *R2*	0.932	0.736

5.4 Heterogeneity Analysis

5.4.1 Heterogeneity in the degree of openness to the outside world

The degree of openness to the outside world reflects the depth of a city's integration into the global economy and is a key factor influencing the upgrading effect of cross-border e-commerce exports. This paper measures openness by the ratio of a city's total import and export volume to its GDP, dividing cities into high and low groups based on the median of the sample. Table 7 shows that in the low openness group, the impact of cross-border e-commerce on the greening and upgrading of exports is not significant; while in the high openness group, the above effects are significantly positive. This indicates that the empowering effect of cross-border e-commerce on the upgrading of export structure is more prominent in cities with a high level of openness. The underlying logic is that highly open cities have a more complete international logistics network, rich trade experience, and a mature business environment, reducing cross-border coordination costs and entry barriers. In addition, export enterprises in such cities are deeply integrated with the international market, enabling them to more quickly capture global green consumption trends and cutting-edge technological developments, allowing the market demand signals transmitted by cross-border e-commerce to be transformed into substantial adjustments in the export structure more quickly. Conversely, low openness cities are limited by logistics channels, foreign trade experience, and institutional shortcomings, hindering the transmission and release of this effect.

Table 7: Heterogeneity Test I

Variable	Low degree of openness to the outside world		High degree of openness to the outside world	
	(1)	(2)	(3)	(4)
	Green	*Sophistication*	*Green*	*Sophistication*
CBEC	0.190	1.414	0.030 *	0.045 *
	(0.701)	(0.873)	(0.017)	(0.025)
Year fixed effect	yes	yes	yes	yes
Urban fixed effects	yes	yes	yes	yes
Sample size	1163	1163	1159	1159
Adjust *R2*	0.458	0.421	0.502	0.561

5.4.2 Heterogeneity in the degree of government intervention

Table 8: Heterogeneity Test II

Variable	Low level of government intervention		High level of government intervention	
	(1)	(2)	(3)	(4)
	Green	*Sophistication*	*Green*	*Sophistication*
CBEC	0.023	-0.132	0.030 *	0.060 *
	(0.138)	(0.196)	(0.018)	(0.031)
Year fixed effect	yes	yes	yes	yes
Urban fixed effects	yes	yes	yes	yes
Sample size	1156	1156	1159	1159
Adjust *R2*	0.573	0.594	0.524	0.565

The degree of government intervention reflects the role of local governments in economic activities and resource allocation. This paper measures the degree of government intervention by the proportion of urban fiscal expenditure to GDP, and also divides the cities into high and low groups based on the median for regression analysis. The results in Table 8 show that in columns (3) and (4), i.e., cities with a higher degree of government intervention, the impact of cross-border e-commerce on the greening and upgrading of exports is significantly positive; while in columns (1) and (2), the impact is not significant in the low intervention group. This indicates that government intervention effectively strengthens the role of cross-border e-commerce in promoting the upgrading of export structure. The reason for this is that cross-border e-commerce, as a new form of foreign trade, is highly dependent on institutional infrastructure such as customs clearance facilitation, tax incentives, and financial support. A high degree of intervention often means that local governments can provide more proactive policy guidance and institutional supply, effectively reducing the institutional friction costs of the new business model; while in cities with weaker government intervention, the lag in institutional support restricts the operational efficiency and empowerment

of cross-border e-commerce. This further shows that institutional innovation and policy support from an "active government" are important guarantees for cross-border e-commerce to release the dividends of structural upgrading.

6. Conclusions

6.1 Research Conclusions

This paper, based on panel data from Chinese prefecture-level and above cities from 2015 to 2024, examines the impact of cross-border e-commerce development on export structure upgrading from two dimensions: export greening and export sophistication. It further analyzes the mechanisms of green technology innovation and resource allocation efficiency, as well as the heterogeneity characteristics under different degrees of openness and government intervention. The results show that cross-border e-commerce development can significantly promote the upgrading of urban export structures. However, this effect is not only direct but also occurs through technological innovation and resource allocation, and is influenced by the degree of urban openness and the institutional environment. Specifically, the main conclusions are as follows.

First, the development of cross-border e-commerce can significantly promote the upgrading of export structure, while simultaneously driving the greening and sophistication of exports. Benchmark regression results show that, after controlling for factors such as economic development level, financial development level, level of openness to the outside world, human capital, industrial structure, fiscal revenue and expenditure pressure, degree of government intervention, and mobile phone penetration rate, and controlling for fixed effects of city and year, the level of cross-border e-commerce development has a significantly positive impact on both export greening and export sophistication. Specifically, for every 1 unit increase in the level of cross-border e-commerce development, the level of export greening increases by approximately 0.046 units, and the level of export sophistication increases by approximately 0.049 units. This indicates that the development of cross-border e-commerce not only promotes the export of green products and improves the environmental friendliness of exported products, but also drives more resources to be transferred to high-tech, high-value-added product sectors, thereby improving the technological structure of exported products.

Second, the conclusion that cross-border e-commerce promotes the upgrading of export structure is robust. After replacing the original explained variables with the export value of green products and high-tech products respectively, the estimated coefficients of the development level of cross-border e-commerce remain significantly positive. Furthermore, after removing the sample from the 2020-2022 pandemic period, the promoting effect of cross-border e-commerce on the greening and upgrading of exports remains significant. Meanwhile, considering the potential two-way causal relationship between the development of cross-border e-commerce and export structure, this paper uses the mean of the development level of cross-border e-commerce in other cities within the same province in the same year as an instrumental variable for 2SLS estimation. After dealing with potential endogeneity issues, the promoting effect of cross-border e-commerce remains significant. This indicates that the positive impact of cross-border e-commerce on the upgrading of export structure is not driven by specific indicator selection, special year shocks, or simple reverse causal relationships.

Third, green technology innovation is a crucial channel for cross-border e-commerce to promote the greening of exports. Mechanism testing results show that the development of cross-border e-commerce has a significant promoting effect on urban green technology innovation, with a regression coefficient of 1.372, which is significant at the 1% statistical level. Cross-border e-commerce helps enterprises more directly access international market green demands and environmental standards, while simultaneously enhancing their green innovation motivation through market competition, knowledge dissemination, and the agglomeration of productive services. Green technology innovation further promotes the green transformation of production processes and the development of environmentally friendly products, improving the international market competitiveness of green products, thereby driving the transformation of urban export structures towards a greener direction.

Fourth, improved resource allocation efficiency is a crucial mechanism for cross-border e-commerce to promote the upgrading of exports. Empirical results show that the development of cross-border e-commerce has a significant positive impact on urban total factor productivity, with an estimated coefficient of 0.288 for the core explanatory variable, which is significant at the 1% statistical level. Cross-border e-commerce reduces the costs of information search, transactions, and market matching through digital platforms, breaks through the spatial limitations of traditional trade, expands the flow of production factors such as capital, labor, and technology, and makes resources more inclined to be allocated to high-productivity and high-tech sectors. As resource allocation efficiency improves, high-tech industries receive more high-quality factor support, thereby increasing the technological complexity and R&D density of export products, ultimately promoting the upgrading of the export structure.

Fifth, the role of cross-border e-commerce in promoting export structure upgrading exhibits significant city-specific heterogeneity, with its effects being more pronounced in cities with higher levels of openness and government intervention. Grouped regression results show that in cities with low levels of openness, the impact of cross-border e-commerce on export greening and upgrading is insignificant, while in highly open cities, both effects are significantly positive. This indicates that a more comprehensive international logistics network, richer foreign trade experience, and a more mature business environment help cross-border e-commerce translate international market demand information into export structure adjustments. Meanwhile, in cities with higher levels of government intervention, cross-border e-commerce significantly promotes both export greening and upgrading, while the effect is not significant in the low-intervention group. This suggests that customs facilitation, financial support, and related institutional supply are important external conditions for cross-border e-commerce to exert its export

structure upgrading effect.

In summary, the research questions in this paper can be answered relatively clearly: the development of cross-border e-commerce can significantly promote the upgrading of urban export structure, and its impact is reflected in both the greening and upgrading of exports; in terms of the mechanism of action, cross-border e-commerce mainly improves the greening level of exports by promoting green technology innovation and promotes the upgrading of exports by improving resource allocation efficiency; at the same time, the degree of openness of cities to the outside world, as well as government policy support and institutional supply, will affect the realization of the above-mentioned promotion effects.

6.2 Policy Recommendations

Based on the above research findings, in order to further leverage the role of cross-border e-commerce in promoting the transformation and upgrading of my country's export structure, this paper proposes the following policy recommendations.

First, improve the infrastructure and public service system for cross-border e-commerce to shift its focus from scale expansion to quality improvement. Cross-border e-commerce can simultaneously promote the greening and upgrading of exports. Therefore, all regions should further improve digital infrastructure, cross-border logistics networks, overseas warehouses, cross-border payment, and customs clearance service systems to reduce the information search costs, logistics costs, and institutional transaction costs for enterprises conducting cross-border trade. At the same time, collaboration between cross-border e-commerce platforms and manufacturing enterprises should be strengthened to guide traditional export enterprises to utilize cross-border e-commerce platforms to more promptly obtain information on overseas consumer demand, green consumption preferences, and technological development trends, thus driving export enterprises to shift from simply relying on cost advantages to competitive advantages in technology, quality, brand, and green practices. Especially for cities with relatively weak foundations in cross-border e-commerce development, measures such as improving logistics nodes, digital networks, and cross-border trade public service platforms can narrow the development gap between different regions.

Second, strengthen support for green technology innovation and the allocation of high-end production factors, and fully leverage the transmission mechanism of cross-border e-commerce. Given that green technology innovation and resource allocation efficiency are crucial channels for cross-border e-commerce to drive export structure upgrading, the synergy between cross-border e-commerce development policies and science and technology innovation policies, green development policies, and industrial upgrading policies should be further strengthened. On the one hand, support for green technology R&D, green patent transformation, and international certification of green products can be strengthened, encouraging cross-border e-commerce enterprises and export manufacturing enterprises to accelerate the R&D of energy-saving and environmentally friendly technologies and green products based on international market green demands. On the other hand, the information matching advantages of digital platforms should be utilized to guide production factors such as capital, talent, technology, and data to cluster in high-tech industries with high production efficiency, strong R&D capabilities, and significant export potential, thereby improving the overall resource allocation efficiency of cities and providing a stable industrial foundation for the upgrading of exports.

Third, implement differentiated support policies for cross-border e-commerce, focusing on addressing the shortcomings in institutional and trade infrastructure in less open regions. The heterogeneous results indicate that cross-border e-commerce will not automatically generate the same level of export upgrading effect in all cities; its effectiveness requires certain open conditions and institutional support. Therefore, for cities with higher levels of openness and a stronger industrial base, further efforts can be made to promote the deep integration of cross-border e-commerce with high-tech industries, green industries, and brand exports, enhancing their position in the global value chain. For cities with lower levels of openness, the focus should be on improving basic conditions such as international logistics, customs clearance services, foreign trade talent training, and cross-border finance to enhance enterprises' ability to participate in the international market. Furthermore, local governments should improve the precision of policy support and improve institutional infrastructure such as customs clearance facilitation, financing support, tax services, and intellectual property protection, rather than simply expanding the scale of cross-border e-commerce through fiscal subsidies, thereby creating a more stable institutional environment for cross-border e-commerce to promote export structure upgrading.

6.3 Future Research Directions

Although this paper systematically examines the impact of cross-border e-commerce on the upgrading of export structure from two dimensions: export greening and export upgrading, there is still room for further exploration.

First, future research could expand to include more detailed and micro-level data. This paper primarily uses panel data at the city level, which can identify the overall relationship between urban cross-border e-commerce development and export structure, but it struggles to further reveal the production, R&D, product selection, and export decisions of enterprises after entering the cross-border e-commerce market. Future research could incorporate customs data, industrial and commercial enterprise data, patent data, and cross-border e-commerce platform data to examine how cross-border e-commerce impacts the quality, technological complexity, green innovation, and global value chain participation of enterprises at the enterprise level, thereby further identifying the micro-mechanisms by which cross-border e-commerce influences export structure upgrading.

Secondly, the spatial spillover effects of cross-border e-commerce development can be further examined. The cross-border e-commerce industry exhibits strong agglomeration and network externalities. The development of

a city's cross-border e-commerce infrastructure and industrial ecosystem can influence surrounding cities through logistics networks, knowledge diffusion, supply chain connections, and demonstration effects. Therefore, future research could introduce spatial econometric models to examine whether cross-border e-commerce has spatial spillover effects across cities or regions, and further analyze the spatial transmission mechanism of cross-border e-commerce on export structure upgrading under the background of coordinated regional development.

Finally, we can further enrich the measurement methods for export structure upgrading and cross-border e-commerce development, and examine more diverse influencing mechanisms. This paper mainly uses the proportion of green product exports and high-tech product exports to measure export structure upgrading, while using comprehensive indicators to measure the development level of cross-border e-commerce in cities. In the future, we can further introduce indicators such as export technology complexity, product quality, export domestic value added, global value chain position, and export market diversification to characterize export structure upgrading from more dimensions. At the same time, we can also examine the potential mechanisms of action such as digital finance, human capital accumulation, industrial agglomeration, supply chain resilience, and enterprise digital transformation, thereby more comprehensively revealing the inherent logic of cross-border e-commerce's impact on high-quality export development.

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