

Driving Circulation Industry Modernization Through Cross-Border E-Commerce

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Abstract: *In the context of economic globalization, the rapid expansion of cross-border e-commerce (CBEC) is profoundly reshaping the circulation industry. This study investigates the driving effect of CBEC on the modernization of the circulation industry through a combined theoretical and empirical approach. The results demonstrate that CBEC significantly promotes circulation industry modernization, with this effect being mediated by the moderating roles of industrial structure optimization and technological innovation. These findings not only enrich the theoretical framework linking CBEC and circulation industry development but also offer actionable insights for policymakers and practitioners seeking to leverage CBEC as a strategic tool for industry transformation and sustainable growth.*

Keywords: Cross-border E-commerce; Modernization of the Circulation Industry; Upgrading of Industrial Structure; Technological Innovation.

1. INTRODUCTION AND LITERATURE REVIEW

As the intersection of digital economy and international trade, cross-border e-commerce has broken through traditional geographical restrictions, providing a broader market and more convenient channels for commodity circulation. Its impact is not only reflected in the growth of trade volume, but also in the profound changes to the entire circulation system. However, in the actual development process, the integration of cross-border e-commerce and the circulation industry still faces many challenges, such as the improvement of the logistics system, the application of information technology, and the optimization of supply chain management. Especially for the modernization development of the circulation industry, it is urgent to solve problems such as low efficiency, high costs, and insufficient informatization. In view of this, this paper aims to analyze the driving role of cross-border e-commerce development on the modernization of the circulation industry through in-depth theoretical exploration and empirical testing, and reveal the influencing mechanisms and paths. This not only helps to enrich and improve the theoretical system of cross-border e-commerce and circulation industry development, but also has positive practical significance for guiding practice and promoting policy innovation.

The modernization development of the circulation industry and the rise of cross-border e-commerce are important topics in the current economic field. Many scholars have conducted in-depth research on this, exploring the realization path of circulation industry modernization and the profound impact of cross-border e-commerce on the industrial structure. First, in terms of the modernization development of the circulation industry, early research mainly focused on improving circulation efficiency and cost control. Ma Chen (2019) pointed out that the key to the modernization of the circulation industry lies in the application of information technology and the optimization of supply chain management. Subsequently, Yu Tonghui (2020) further emphasized the importance of data-driven decision-making systems in the modern circulation industry. The research of Liu Jianhu (2021) shows that intelligent and automated technologies play a key role in promoting the modernization of the circulation industry.

Second, in terms of the development of cross-border e-commerce and its impact, there have also been many research results in recent years. Ma Shuzhong (2021) believes that cross-border e-commerce has broken through traditional trade barriers and provided new opportunities for small and medium-sized enterprises to expand into the international market. Zhao Xiaohan (2022) analyzed how cross-border e-commerce affects shopping habits and market trends from the perspective of consumer behavior. Wang Na (2023) deeply explored the role of cross-border e-commerce in promoting global trade balance and pointed out its role in driving the upgrading of the circulation industry.

Finally, specifically in terms of the impact of cross-border e-commerce on the circulation industry, scholars' research has become increasingly in-depth. The research of Ma Lingang (2023) shows that cross-border e-commerce significantly improves circulation efficiency by optimizing the supply chain and logistics system. Ji Xiaoguang (2024) further pointed out that cross-border e-commerce not only changes the traditional circulation mode, but also promotes the innovation and restructuring of the circulation industry.

To sum up, the existing literature has conducted extensive and in-depth research on the modernization of the circulation industry, the development of cross-border e-commerce, and their impacts. However, these studies mostly focus on single aspects and lack comprehensive analysis that combines cross-border e-commerce with the modernization of the circulation industry. Through the combination of theoretical exploration and empirical testing, this paper introduces the moderating variables of industrial structure upgrading and technological innovation to deeply analyze the driving effect of cross-border e-commerce on the modernization of the circulation industry. Therefore, the innovation of this paper lies in: systematically exploring the internal relationship between cross-border e-commerce and the modernization of the circulation industry, and verifying the positive promotion effect of cross-border e-commerce on the modernization of the circulation industry through empirical data, providing valuable reference for policy-making and industrial development in practice.

2. THEORETICAL EXPLORATION

2.1 Direct Impact of Cross-border E-commerce Development on the Modernization of the Circulation Industry

The rapid development of cross-border e-commerce has had a profound impact on the modernization of the circulation industry, mainly reflected in the following three aspects:

Firstly, in terms of the modernization of the circulation industry environment, the rise of cross-border e-commerce has greatly broadened the market boundaries. The traditional circulation industry was restricted by geography and time, while cross-border e-commerce has broken these limitations through Internet platforms, enabling goods to circulate around the clock and globally. This not only provides a more convenient shopping experience for consumers but also opens up a new market space for merchants. Through the application of digital technologies, real-time update and sharing of information have been achieved, improving market transparency and transaction efficiency, and creating a more fair, open, and efficient market environment for the circulation industry.

Secondly, in terms of the modernization of industrial development, cross-border e-commerce has promoted the digital transformation of the circulation industry. The traditional circulation industry centered around offline physical stores faced problems such as opaque supply chains and information flow. The rise of cross-border e-commerce has made it possible for the digital transformation of the commercial circulation industry through the deep integration of the Internet and the logistics network. Digital technologies penetrate all aspects of commodity procurement, sales, and logistics distribution, improving the response speed and flexibility of the entire supply chain. Merchants can accurately grasp market demand through data analysis, optimize inventory management, and reduce operating costs, thus enhancing the overall competitiveness of the industry.

Finally, in terms of the modernization of industrial potential, cross-border e-commerce has brought new growth points to the circulation industry. With the growing global demand for personalized and high-quality goods, cross-border e-commerce has become an important channel to meet these demands. Merchants can directly face global consumers through cross-border e-commerce platforms, launch products that meet market needs, and continuously optimize the product mix. At the same time, cross-border e-commerce also promotes local economic growth by reducing trade barriers and improving circulation efficiency, injecting new vitality into local economies. In addition, cross-border e-commerce has also driven the development of related industrial chains, such as logistics, payment, and information technology, laying a solid foundation for the future development of the circulation industry. In summary, the development of cross-border e-commerce has had a profound impact on the modernization of the circulation industry, not only optimizing the market environment, promoting the digital transformation of the industry, but also bringing new growth potential to the industry.

H1: Cross-border e-commerce can effectively drive the improvement of the modernization level of the circulation industry.

2.2 Moderating Role of Industrial Structure Upgrade and Technological Innovation

As China's economy continues to deeply integrate into the global industrial chain, industrial structure upgrade and technological innovation have become important factors driving high-quality economic development. Particularly in the context of the rapid development of cross-border e-commerce, the optimization of industrial structure and technological innovation are particularly important for enhancing the modernization level of the circulation

industry. Therefore, this paper introduces industrial structure and technological innovation as moderating variables to deeply analyze the impact mechanism of cross-border e-commerce on the modernization development of the circulation industry.

First, the industrial structure has a significant moderating effect on the promotion of the circulation industry modernization by cross-border e-commerce. A reasonable industrial structure can optimize resource allocation, improve production efficiency, and thus promote the rapid development of cross-border e-commerce. In the circulation industry, the optimization of industrial structure means more efficient supply chain management and more reasonable industrial layout, which helps cross-border e-commerce enterprises better integrate resources, improve logistics efficiency, and thus promote the modernization of the circulation industry. Specifically, a highly developed tertiary industry, especially modern service industries, can provide more convenient and efficient service support for cross-border e-commerce, such as fast delivery, precise marketing, etc., and thus enhance the modernization level of the circulation industry.

Second, technological innovation plays a crucial role in the process of cross-border e-commerce promoting the modernization of the circulation industry. Technological innovation can not only improve the operation efficiency of cross-border e-commerce platforms but also enhance the positive relationship between cross-border e-commerce and the modernization development of the circulation industry. By introducing advanced technological means, cross-border e-commerce enterprises can achieve precise prediction of market demand, intelligent management of the supply chain, and personalized customization of customer service. These technological innovations not only improve the operation efficiency and service quality of cross-border e-commerce but also promote technological innovation and model innovation in the circulation industry, further accelerating the process of circulation industry modernization.

In summary, industrial structure and technological innovation play an important moderating role in the process of cross-border e-commerce promoting the modernization development of the circulation industry. The optimization of industrial structure provides a better development environment for cross-border e-commerce, while technological innovation enhances the positive impact of cross-border e-commerce on the modernization development of the circulation industry. The combined effect of these two makes cross-border e-commerce play a greater role in promoting the modernization process of the circulation industry. Therefore, this paper proposes the following research hypotheses:

H2: The industrial structure has a positive moderating effect on the cross-border e-commerce-driven modernization development of the circulation industry.

H3: Technological innovation can enhance the positive relationship between cross-border e-commerce and the modernization development of the circulation industry.

3. RESEARCH DESIGN

3.1 Variable Setting

1) Explained variable: Modernization of the circulation industry. The modernization of the circulation industry refers to a series of reforms and innovations carried out in the field of commodity circulation along with the processes of industrialization, urbanization, and informatization. These reforms and innovations aim to form a commodity circulation system with low costs, high efficiency, and high benefits. Essentially, the modernization of the circulation industry is a process of transforming traditional circulation industries into modern ones. Therefore, referring to the research methods of Zhao Zhiming (2019) and Gan Yuanling (2024), this paper comprehensively evaluates the modernization development of the circulation industry from three aspects: modernization of the industrial environment, modernization of industrial development, and modernization of industrial potential. As shown in Table 1, it is measured using the entropy value method and denoted as MCI.

2) Explanatory variable: Cross-border e-commerce. The development of cross-border e-commerce refers to the process of commodity transactions between trading parties in different countries or regions with the help of e-commerce platforms. This process covers multiple links such as commodity selection, electronic payment, cross-border logistics distribution, and off-site warehousing. It is an international business activity that involves the comprehensive application and coordinated development of multiple fields such as information technology, online payment systems, logistics services, and e-commerce platforms. Therefore, based on the research of Yang Fan

(2023), this paper comprehensively determines the development level of cross-border e-commerce from three aspects: development scale index, application penetration index, and development ability index. As shown in Table 2, it is denoted as CEBC.

Table 1: Evaluation Index System for the Modernization Development of the Circulation Industry

Goal Layer	Sub - indicator	Indicator Content	Indicator Direction
Modernization of the Circulation Industry	Modernization of the Industrial Environment	Output Value of the Circulation Industry per Capita	+
		Number of Express Deliveries per Capita	+
		Total Online Retail Sales per Capita	+
	Modernization of Industrial Development	Internet Penetration Rate	+
		Total Length of Optical Cable Lines	+
		Number of Internet Access Ports per Capita	+
	Modernization of Industrial Potential	Number of Post Offices per Capita	+
		Proportion of Enterprise E - commerce Sales	+
		Proportion of Enterprise E - commerce Purchases	+

3) Moderating variables: industrial structure upgrading and technological innovation. Referring to the method of Tang Hongtao (2024), this paper selects the ratio of the output value of the tertiary industry to the output value of the secondary industry as the proxy variable for industrial structure upgrading, denoted as Ind; and uses the number of patent authorizations as the proxy indicator for technological innovation, denoted as Intec.

4) Control variables: To further reduce the errors caused by relevant variables, this paper selects the following relevant control variables: economic development level, using per capita GDP as the proxy variable, denoted as GDP; foreign investment level, measured by the ratio of foreign direct investment to GDP, denoted as FDI; infrastructure construction, measured by the fixed asset investment, denoted as IC; government intervention degree, measured by the ratio of government fiscal expenditure to GDP, denoted as GOV.

3.2 Model Construction

Based on the mechanism analysis and variable setting of the direct effect above, the following econometric model is first established:

$$MCI_{i,t} = \alpha_0 + \alpha_1 CEBC_{i,t} + \alpha_2 CV_{i,t} + \varepsilon_{i,t} \quad (1)$$

Table 2: Evaluation Index System for the Development Level of Cross-border E-commerce

Goal Layer	Sub - indicator	Indicator Content	Indicator Direction
Cross - border E - commerce Development Level	Development Scale Index	Cross - border E - commerce Transaction Volume	+
		Total Volume of Air Cargo Transportation	+
		Total Number of Cross - border E - commerce Employees	+
	Application Penetration Index	Number of International Express Deliveries	+
		Proportion of E - commerce Transaction Volume in GDP	+
		Proportion of the Number of E - commerce Transaction Enterprises	+
	Development Capacity Index	Number of Patent Applications	+
		Number of College Graduates	+
		Total Number of Scientific Research Personnel	+

Table 3: Baseline Regression Results

Variable	(1)	(2)
CEBC	0.136*** (0.006)	0.084*** (0.009)
GDP	-	0.061*** (0.013)
FDI	-	0.038 (0.030)
IC	-	0.017 (0.009)
GOV	-	0.453*** (0.045)
cons	-0.830*** (0.095)	0.038 (0.030)
R ²	0.472	0.483

Note: The values in parentheses are T values. *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively. The same applies hereinafter.

Table 4: Results of Moderating Effect Regression

Variable	Upgrading of industrial structure		Technological innovation	
	(1)	(2)	(3)	(4)
CEBC	0.067*** (0.008)	0.063*** (0.009)	0.062*** (0.007)	0.067*** (0.009)
Ind	0.107*** (0.027)	0.254*** (0.024)	-	-
Intec	-	-	0.093*** (0.016)	0.101*** (0.017)
CEBC × Ind	-	0.061*** (0.005)	-	-

CEBC $\times$ Intec	-	-	-	0.016*** (0.002)
Control variables	Yes	Yes	Yes	Yes
cons	-3.079*** (0.590)	-3.106*** (0.582)	-3.108*** (0.613)	-3.121*** (0.607)
R^2	0.425	0.562	0.517	0.542

Among them, i represents the research province, t represents the research period, MCI represents the modernization level of the circulation industry, $CEBC$ represents the development level of cross-border e-commerce, CV represents relevant control variables, and ε represents the random error term.

Secondly, to explore whether industrial structure upgrading and technological innovation play a moderating role between cross-border e-commerce and the modernization of the circulation industry, based on the setting of the previous hypothesis H2, the following moderating effect model is established:

$$\begin{aligned} MCI_{i,t} &= \beta_0 + \beta_1 CEBC_{i,t} + \beta_2 CEBC \times Ind_{i,t} + \beta_3 Ind_{i,t} + \beta_4 CV_{i,t} + \varepsilon_{i,t} \\ MCI_{i,t} &= \varphi_0 + \varphi_1 CEBC_{i,t} + \varphi_2 CEBC \times Intec_{i,t} + \varphi_3 Intec_{i,t} + \varphi_4 CV_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (3)$$

Among them, $CEBC \times Ind$ represents the interaction term between cross-border e-commerce and industrial structure upgrading, and $CEBC \times Intec$ represents the interaction term between cross-border e-commerce and technological innovation.

3.3 Data Sources

This paper uses the panel data of 30 provinces (excluding Hong Kong, Macao, Taiwan regions and Tibet) in China from 2012 to 2022 as the research object. The main indicator data are sourced from the "China Statistical Yearbook", "China Foreign Economic and Trade Statistical Yearbook", "China Tertiary Industry Statistical Yearbook" and the statistical bulletins of each province and city.

4. EMPIRICAL ANALYSIS AND EXPLORATION

4.1 Baseline Regression Analysis

To test the impact of cross-border e-commerce on the modernization of the circulation industry, this paper uses a fixed-effects model for testing, and the results are shown in Table 3. Column (1) shows that without adding control variables, only the impact of explanatory variables is considered. From the estimated coefficients, the estimated coefficient of cross-border e-commerce is 0.136 and is significant at the 1% level; Column (2) shows that after adding relevant control variables, the estimated coefficient of cross-border e-commerce is still significantly positive. From a statistical analysis perspective, when the development level of cross-border e-commerce increases by one unit, it will drive the modernization of the circulation industry to increase by 0.084%, verifying the setting of the previous hypothesis H1.

4.2 Moderating Mechanism Analysis

Table 4 shows that when introducing industrial structure and technological innovation as moderating variables and forming an interaction with cross-border e-commerce, cross-border e-commerce still has a significant positive impact on the modernization of the circulation industry. Specifically, the coefficient of the interaction term between industrial structure and cross-border e-commerce is 0.061, and the coefficient of the interaction term between technological innovation and cross-border e-commerce is 0.016, and both are significant at the 1% statistical level. This indicates that the optimization and upgrading of industrial structure and technological innovation play a substantial moderating role in the process of cross-border e-commerce facilitating the modernization of the circulation industry.

From the perspective of the real background, international trade in the Internet era is increasingly shifting online. The continuous optimization of the industrial structure enables production factors to flow towards more efficient service industries, and resources are reallocated to industries with higher production efficiency. This reallocation of resources not only improves the overall resource utilization efficiency but also promotes the pace of modernization of the circulation industry. In addition, cross-border e-commerce breaks through the traditional time and space limitations and creates a platform for technological exchanges and resource integration. The knowledge and technology spillovers brought about by the agglomeration effect of cross-border e-commerce provide new impetus for technological innovation. These innovations not only give birth to new products and new materials

but may also lead to new changes in the demand structure. In order to respond to higher-level market demands and gain a competitive advantage, technological innovation reduces operating costs by improving production processes and enhancing circulation efficiency, thereby reducing resource waste. Therefore, it can be clearly seen that the upgrading of industrial structure and technological innovation play a crucial moderating role in cross-border e-commerce promoting the modernization of the circulation industry, which also verifies Hypothesis H2 and Hypothesis H3 proposed above.

4.3 Robustness Tests

To further determine the reliability of the benchmark results, this paper conducts robustness tests by replacing the explanatory variables, changing the measurement method of the explained variable, and excluding municipalities directly under the central government. First, this paper adopts the method of Liu Ye (2024) and selects the cross-border e-commerce operating income of each province as a replacement indicator for the explanatory variable, and reintroduces it into the analysis. The results are shown in column (1) of Table 5. It can be seen that after replacing the explanatory variables, cross-border e-commerce still has a significant positive impact on the modernization development of the circulation industry. Second, this paper uses the principal component analysis method to remeasure the level of modernization development of the circulation industry. The results are shown in column (2) of Table 5. The estimated coefficient of cross-border e-commerce development is 0.082 and is significant at the 1% level, verifying the reliability of the previous conclusion again. Finally, this paper excludes the municipalities directly under the central government from the research object, and the conclusion still holds after remeasurement.

5. POLICY RECOMMENDATIONS

First, strengthen the construction of cross-border e-commerce infrastructure. Given the significant role of cross-border e-commerce in promoting the modernization of the circulation industry, it is recommended that the government further increase investment in cross-border e-commerce infrastructure. This includes enhancing network coverage and quality, optimizing the logistics and distribution system, and strengthening the construction of information technology facilities such as data centers and cloud computing. Through these measures, the operational efficiency of cross-border e-commerce can be effectively improved, thereby promoting the modernization process of the circulation industry.

Second, promote the optimization and upgrading of the industrial structure. This study finds that the industrial structure plays an important regulatory role in the promotion of the modernization of the circulation industry by cross-border e-commerce. Therefore, the government should guide and support enterprises to adjust their industrial structure and transform towards high-tech and high-value-added directions. At the same time, encourage traditional circulation enterprises to cooperate with cross-border e-commerce platforms to achieve the integrated development of online and offline, and enhance the competitiveness of the entire industrial chain.

Third, promote technological innovation and talent cultivation. Technological innovation is the key driving force for the development of cross-border e-commerce and the modernization of the circulation industry. The government should increase investment in technological innovation, support enterprises to carry out R & D activities, and promote the application of new technologies in cross-border e-commerce and the circulation industry. At the same time, attach importance to the cultivation and introduction of relevant talents to provide talent guarantee for the sustainable and healthy development of the industry.

Fourth, improve the relevant regulatory and standard systems. To ensure the healthy development of cross-border e-commerce and the circulation industry, the government should accelerate the improvement of relevant regulatory and standard systems. This includes formulating and implementing more stringent consumer rights protection regulations, establishing and improving the quality supervision mechanism for cross-border e-commerce products, and promoting the docking and mutual recognition of international standards. Through these measures, a good legal environment can be provided for the modernization development of cross-border e-commerce and the circulation industry.

Table 5: Robustness Test

Variable	(1)	(2)	(3)
CEBC	0.091*** (0.010)	0.082*** (0.009)	0.071*** (0.010)
Control variable	Yes	Yes	Yes
cons	-9.283*** (0.614)	-7.280*** (0.627)	-7.454*** (0.650)
R ²	0.574	0.513	0.403

Fifth, strengthen international cooperation and exchanges. Cross-border e-commerce has the natural global characteristic, so strengthening international cooperation and exchanges is of great significance for promoting its development. The government should actively participate in the formulation and negotiation of international economic and trade rules, and promote the establishment of a more open, fair and transparent international trade environment. At the same time, encourage and support enterprises to "go global", participate in international market competition and cooperation, and enhance the international competitiveness of China's cross-border e-commerce and circulation industries.

FUNDED PROJECTS:

Research on the Decision-making Support System for the Coordinated Development of the Guangdong-Hong Kong-Macao Greater Bay Area (No. 2025ZDJS127), a project for enhancing the scientific research capabilities of key construction disciplines in Guangdong Province in 2022; Research on the Digital Marketing Strategies of Guangdong's Foreign Trade Enterprises under the Background of Cross-border E-commerce (No. 2025HSQX098), a youth academic research project of Guangzhou Huashang College in 2025.

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