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Analysis of Coupling Coordination and Obstacle Factors between Cross-Border E-Commerce and Manufacturing Industrial Belts in Eastern China

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Abstract: Cross-border e-commerce has created new opportunities for Chinas manufacturing sector, and their deep integration holds significant importance for building a new foreign trade development paradigm. Based on panel data from eastern Chinas regions (2017-2024), this study employs the entropy-weighted TOPSIS method to construct a comprehensive evaluation system, establishing coupling coordination models and obstacle degree models to empirically examine the coupling development relationship and obstacles between cross-border e-commerce and manufacturing industrial clusters. The research reveals that the coupling coordination degree between these two systems in eastern regions generally demonstrates positive synergistic trends. However, with the exception of Guangdong Province, most provinces remain at medium-to-low coordination levels, forming a distinct three-tiered spatial structure. Technological innovation emerges as the primary constraint on the coupling coordination between cross-border e-commerce and manufacturing industrial clusters, followed by market scale and e-commerce logistics. The focal point of coordinated development between the two systems is shifting toward high-quality and efficient transformation.

1. Introduction

With the global economys accelerated digital transformation and evolving consumption patterns, cross-border e-commerce has emerged as a pivotal force in driving economic growth. The report from the 20th National Congress of the Communist of China emphasized: "Develop digital trade and strengthen the construction of a trading powerhouse." As a vital component of digital trade, cross-border e-commerce exemplifies the concrete manifestation of trade digitalization. Meanwhile, manufacturing--the cornerstone of the real economy--is under mounting pressure to transform. Facilitating the deep integration of cross-border e-commerce with manufacturing industrial clusters not only serves as a strategic pivot for nurturing new drivers of foreign trade and fostering innovative business models, but also represents an intrinsic requirement for advancing industries toward higher value-added segments and achieving high-quality economic development.

Current research on cross-border e-commerce and the manufacturing industry focuses on three areas: The impact of cross-border e-commerce on manufacturing development. Scholars have explored their mechanism and paths[1-4]. Zhang Cheng et al. argue that cross-border e-commerce drives manufacturing upgrading through consumption upgrading and technological innovation. Macro-level integration between cross-border e-commerce and manufacturing[5-9], especially the transformation and upgrading of industrial clusters. Micro-level quantitative analysis of their integration [10-12], with resource identification as the core link.

Based on this, this paper combines cross-border e-commerce and manufacturing industrial belts, selects ten provinces and cities in eastern China, and builds a comprehensive evaluation index system. Referring to the method of scholars[15], this paper uses location entropy, entropy-weighted TOPSIS, coupling coordination degree and obstacle degree models to empirically analyze their comprehensive development, spatiotemporal coordination and constraints from 2017 to 2024, so as to provide references for manufacturing development.

2. Empirical Research Design

2.1. Study Area and Data Sources

This paper selects 10 provinces in the eastern region as sample areas. Based on the availability and timeliness of data, the period from 2017 to 2024 is determined as the research period. The data are sourced from the "China Science and Technology Statistical Yearbook", "China Statistical Yearbook", "China Industrial Statistical Yearbook", as well as the Statistical Yearbooks of the Postal Administration, the General Administration of Customs, and various provinces. Missing data for some years are filled in through linear interpolation.

2.2. Construction of Evaluation System

The integration of cross-border e-commerce into manufacturing industrial clusters significantly enhances their competitiveness and resource allocation efficiency. To analyze the coupling coordination between these two systems and identify barriers, the study first measures their integrated development level, then calculates the coupling coordination index, and finally ranks obstacles by severity. Adhering to the principles of scientific rigor, systematicness, and conciseness in indicator selection, this paper draws on existing scholarly research.[16-17]Based on the relevant research, a comprehensive evaluation system for cross-border e-commerce and manufacturing industrial clusters was developed, comprising 7 primary indicators and 16 secondary indicators (Table 1).

Table 1 Cross-border E-commerce and Manufacturing Industrial Belt System Evaluation Index System

System	Primary Indicator	Secondary Indicator	Unit and Indicator Attributes
Cross-Border Electronic Commerce System	Market Size	X1 Density of Cross-border E-commerce Enterprises	%, +
		X2 E-commerce Purchase Amount	100 Million, +
		X3 E-commerce Sales	100 Million, +
	E-commerce Logistics	X4 Cross-border E-commerce Express Volume	10,000 Items, +
	Development Potential	X5 Per Capita Disposable Income of Residents	
		X6 Number of Internet Broadband Access Users	Households, +
		X7 Number of mobile phone subscribers	Households, +
manufacturing industry industrial belt system	Degree of Agglomeration	X8 Location Entropy Coefficient	%, +
	Economic Benefits	X9 Manufacturing Industry Growth Rate	%, +
		X10 Manufacturing Enterprise Profit Margin	%, +

	Technical Innovation	X11 Number of Enterprises with R&D Activities	Individual, +
		X12 R&D Expenditure of Industrial Enterprises above Designated Size	Ten Thousand Yuan, +
		X13 Number of R&D Personnel in Industrial Enterprises	Person, +
		X14 Number of Patent Applications	Piece+
	Factor Input	X15 Total Labor Productivity of Large-scale Industrial Enterprises	%, +
		X16 Industrial Energy Consumption	10,000 Tons of Standard Coal, -

2.3. Systematic Review Methods

2.3.1. Entropy Weight TOPSIS Method

This paper completes the missing value data filling, and obtains the weight proportion of each index based on the entropy weight TOPSIS model. The weighted data matrix is input into the system for TOPSIS evaluation, and the relative difference level of each index is measured scientifically. The specific empirical method is as follows:

The first step is to perform dimensionless processing on the indicators, where Y_{ij} denotes te dimensionless value of the indicator. The calculation formula is as follows:

$$Y_{ij}=\begin{cases}\frac{X_{ij}\text{-min}(X_{ij})}{\max(X_{ij})\text{-min}(X_{ij})}, & \text{if } X_{ij} \text{ is a positive indicator}\\ \frac{\max(X_{ij})\text{-}X_{ij}}{\max(X_{ij})\text{-min}(X_{ij})}, & \text{if } X_{ij} \text{ is a negative indicator}\end{cases} \quad (1)$$

Step 2: Calculate the information entropy E_j of Y_{ij}:

$$E_j=\ln\frac{1}{n}\sum\left[\left(\frac{Y_{ij}}{\sum Y_{ij}}\right)\ln\left(\frac{Y_{ij}}{\sum Y_{ij}}\right)\right] \quad (2)$$

Step 3: Calculate the weight W_j of Y_{ij}:

$$W_j=(1\text{-}E_j)/\sum(1\text{-}E_j) \quad (3)$$

Step 4: Construct the weighted matrix R_{ij} , where $r_{ij}=W_j\times Y_{ij}$:

$$R_{ij}=(r_{ij})_{n\times m} \quad (4)$$

Step 5: Determine the optimal solution Z^+ and the worst solution Z^-,and calculate the euclidean distance d^+ and d^- they represent:

$$Z_j^+=(\max r_{i1},\max r_{i2},\ldots,\max r_{im}) \quad (5)$$

$$Z_j^-=(\min r_{i1},\min r_{i2},\ldots,\min r_{im}) \quad (6)$$

$$d_i^+=\sqrt{\sum_{j=1}^{m}(Z_j^+\text{-}r_{ij})^2} \quad (7)$$

$$d_i^-=\sqrt{\sum_{j=1}^{m}(Z_j^-\text{-}r_{ij})^2} \quad (8)$$

Step 6: Calculate the closeness degree between each evaluation index and the optimal solution:

$$U_i=\frac{d_i^-}{d_i^++d_i^-} \quad (9)$$

2.3.2. Coupling Coordination Degree Model

The coupling coordination degree model is a framework designed to characterize the interaction and coordination among multiple systems or subsystems, primarily quantifying the degree of interplay and alignment within a systems components, with the specific calculation formula as follows:

$$C=\frac{2\sqrt{U_1U_2}}{U_1+U_2} \tag{10}$$

C represent the coupling degree between cross-border e-commerce and the manufacturing industry belt system, while U_1 and U_2 denote the evaluation levels of the two system. A large C value indicates a higher degree of coupling. The coupling coordination model is constructed as follows:

$$D=\sqrt{C\times T} \tag{11}$$

$$T=\alpha U_1+\beta U_2 \tag{12}$$

In the above formula, D denotes the coupling coordination degree between the two systems, with values ranging from 0 to 1, while T represents the comprehensive coordination index. α and β are parameters to be estimated, satisfying the condition $\alpha+\beta=1$, following the methodology of previous studies, we set $\alpha=\beta=0.5$.

Based on the research findings of previous scholars[13,14]. The results of the study classify the coupling coordination degree into six levels: $D\in[0,0.2]$ indicates discoordination, $D\in(0.2,0.4]$ indicates barely coordination, $D\in(0.4,0.5]$ indicates primary coordination, $D\in(0.5,0.6]$ indicates moderate coordination, $D\in(0.6,0.8]$ indicates good coordination, and $D\in(0.8,1]$ indicates excellent coordination.

2.3.3. Obstacle Model

The obstacle degree model diagnoses each indicator by using factor contribution, indicator deviation, and obstacle degree, and ranks them according to the size of obstacle degree, thus determining the primary and secondary relationships of each obstacle factor. Here, O represents the impact degree of each system indicator on the target layer, W is the indicator deviation, indicating the distance between each indicator and the expected value; M denotes the obstacle impact degree of each system indicator on the target layer, and N represents the obstacle impact degree of each subsystem.

$$W_{ij}=1-X_{ij} \tag{13}$$

$$M_{ij}=\frac{O_j\times Y_{ij}}{\sum_{j-1}^{m}(O_j\times Y_{ij})} \tag{14}$$

$$N_{ij}=\sum M_{ij} \tag{15}$$

3. Empirical Results Analysis

3.1. Comprehensive Development Level Evaluation

Building upon the established indicator framework, this study employs the entropy-weighted TOPSIS method to calculate the composite evaluation scores for cross-border e-commerce and manufacturing industrial clusters, as illustrated in Figure 1. From 2017 to 2024, Chinas cross-border e-commerce sector demonstrated steady growth, increasing from 0.15 in 2017 to 0.29 in 2024, reflecting its robust momentum fueled by policy incentives and technological advancements.

However, the growth rate slowed after 2021, likely due to regulatory adjustments in global e-commerce platforms and shifts in international trade dynamics. This indicates that cross-border e-commerce has transitioned from rapid expansion into a phase of structural optimization and quality enhancement. Meanwhile, manufacturing industrial clusters maintained stable growth, rising from 0.21 in 2017 to 0.26 in 2024. Their lower volatility stems from manufacturings greater reliance on industrial upgrading and regional clustering effects, coupled with stronger ties to the real economy.

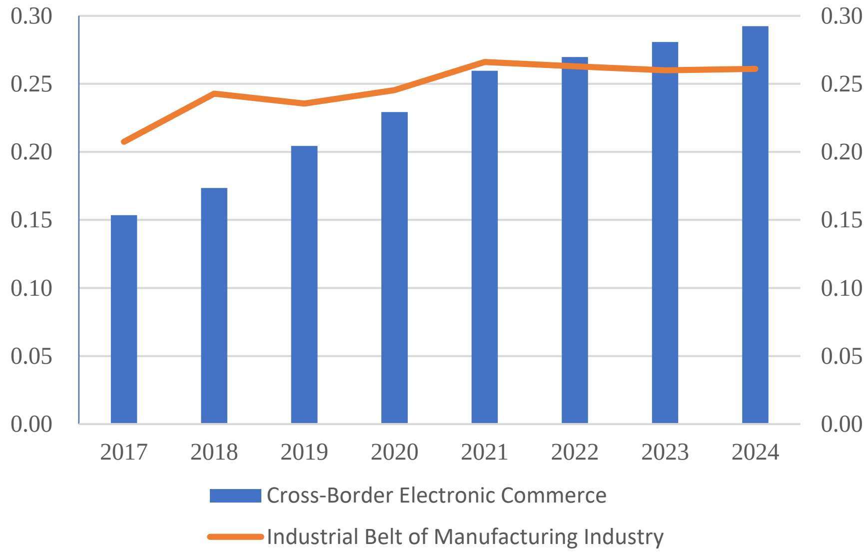

Figure 1: Comprehensive Development Level of Cross-border E-commerce and Manufacturing Industrial Belt in Eastern China (2017-2024)

3.2. Coupling Coordination Degree Analysis

This study employs a coupling coordination model to measure the collaborative development level between cross-border e-commerce and manufacturing industrial clusters in eastern China from 2017 to 2024, with four representative years selected for detailed analysis as shown in Table 2 and Table 3. Temporally, the coupling coordination degree between these systems in the eastern region has maintained relative stability with gradual improvement. Overall, the region has achieved a transition from the lower limit of "barely coordinated" to the upper edge of "primary coordination," indicating a gradual shift from loose connections to orderly collaboration. However, regional disparities show a trend of gradient solidification, with the coupling coordination degree remaining at a moderately low level. The mutual promotion effect between the two systems still has significant room for improvement.

From a spatial distribution perspective, between 2017 and 2024, the eastern region lacked high-quality coordinated development zones. Areas with imbalanced development and decline were represented by Hainan, while regions with primary or higher coupling coordination levels were mainly concentrated in Jiangsu, Shandong, Zhejiang, and Guangdong. Other areas also exhibited coupling coordination levels near the imbalance and decline stage, forming an overall three-tiered ladder structure.

Table 2 Coupling Coordination Degree of Cross-border E-commerce and Manufacturing Industrial Belt in Various Provinces

	2018		2020		2022		2024	
	degree of coupling	coupling coordination degree	degree of coupling	coupling coordination degree	degree of coupling	coupling coordination degree	degree of coupling	coupling coordination degree
Beijing	0.4994	0.2595	0.4389	0.2708	0.4108	0.2841	0.3172	0.2666
Tianjin	0.8901	0.2956	0.9083	0.3384	0.7432	0.3451	0.7886	0.3383
Hebei	0.7409	0.3340	0.7725	0.3492	0.8172	0.3689	0.8833	0.3844
Shanghai	0.6088	0.3464	0.4696	0.3344	0.4103	0.3337	0.3663	0.3325
Jiangsu	0.5900	0.4109	0.5577	0.4278	0.5637	0.4612	0.6588	0.5141
Zhejiang	0.4846	0.4145	0.8442	0.5277	0.9197	0.5759	0.8084	0.5415
Fujian	0.7017	0.2906	0.7524	0.3205	0.8000	0.3565	0.8486	0.3744
Shandong	0.7459	0.4168	0.7021	0.4208	0.6895	0.4636	0.7895	0.5091
Guangdong	0.9992	0.6488	0.8469	0.6847	0.8496	0.7099	0.8755	0.7369
Hainan	0.1792	0.1239	0.2898	0.1558	0.4448	0.1724	0.7270	0.1929

Table 3 Classification Results of Coupling Coordination Degree in Eastern Region

grade	2018	2020	2022	2024
disregulation	Hainan	Hainan	Hainan	Hainan
barely coordinated	Beijing, Tianjin, Hebei, Shanghai, Fujian	Beijing, Tianjin, Hebei, Shanghai, Fujian	Beijing, Tianjin, Hebei, Shanghai, Fujian	Beijing, Tianjin, Hebei, Shanghai, Fujian
primary coordination	Jiangsu, Zhejiang, Shandong	Jiangsu, Shandong	Jiangsu, Shandong	
moderate coordination		Zhejiang	Zhejiang	Jiangsu, Shandong, Zhejiang
Good coordination	Guangdong	Guangdong	Guangdong	Guangdong
Quality Coordination				

3.3. Analysis of Impairment Factors

(1) Barrier Factor at the Criterion Level

As illustrated in Figure 2, the statistical analysis of barriers across seven criterion levels for cross-border e-commerce and manufacturing industrial clusters in eastern China reveals significant changes from 2017 to 2024. Economic efficiency, technological innovation, and factor input showed an upward trend, while market scale and development potential declined. Meanwhile, e-commerce logistics and industrial agglomeration levels remained relatively stable.

From the perspective of obstacle levels, technological innovation remains the primary constraint on the coupling and coordination between cross-border e-commerce and manufacturing industrial clusters, followed by market scale and e-commerce logistics, while the obstacles to development potential continue to decline. Throughout the study period, the degree of technological innovation obstacles significantly exceeded those related to market scale and e-commerce logistics, with the latter continuing to rise. Although market scale obstacles were initially higher than e-commerce logistics obstacles, after 2021, market scale obstacles began to decrease while e-commerce logistics obstacles gradually increased annually, narrowing the gap between the two. Additionally, while obstacles related to economic efficiency and factor input increased year by year, their growth rate remained slow, and the changes in agglomeration degree obstacles were relatively minor.

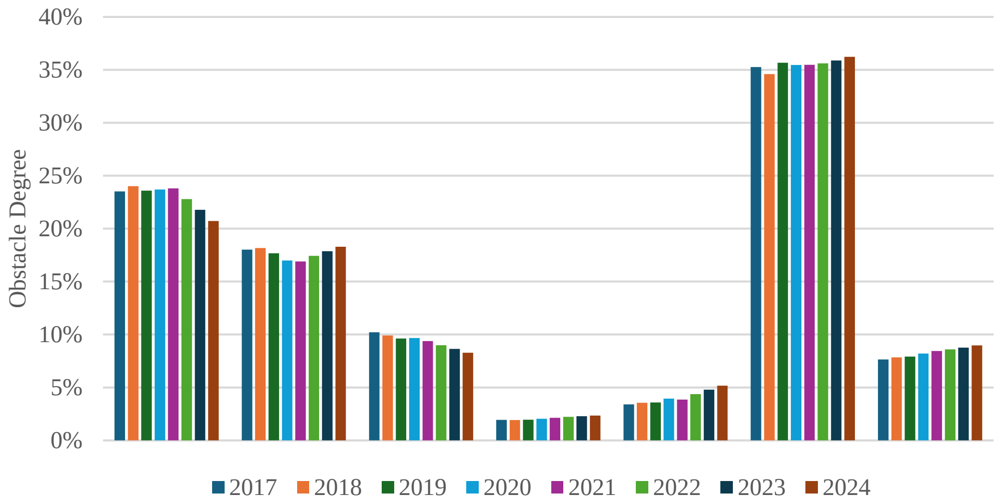

Figure 2: Obstacle Level of Cross-border E-commerce and Manufacturing Industrial Belt System in Eastern China (2017-2024)

(2) Barrier Factors at the Indicator Level

To accurately identify the key factors constraining the coupling and coordination between cross-border e-commerce and manufacturing industrial clusters, this study selected the top 8 factors based on their obstacle levels across indicator tiers. In 2017, the top eight obstacles primarily included cross-border e-commerce express delivery volume, R&D personnel numbers in large-scale industrial enterprises, enterprise density of cross-border e-commerce, and patent applications. By 2021, total labor productivity in large-scale industrial enterprises had entered the top 8, and by 2024, this ranking had been further consolidated. Key indicators related to industrial foundations and innovation capabilities remained core obstacles. Traditional digital infrastructure metrics such as internet broadband access users and mobile phone penetration rates had become relatively well-established, yet their obstacle levels never ranked in the top eight. This indicates that cross-border e-commerce express delivery volume, R&D personnel numbers in large-scale industrial enterprises, enterprise density of cross-border e-commerce, and patent applications remain the most critical elements for enhancing cross-border e-commerce and manufacturing industrial cluster coordination. In the later stages of coordinated development, the importance of factor utilization efficiency becomes increasingly prominent, with the focus of constraints shifting from "presence" to "quality".

Among all indicators, the most significant barrier factor is cross-border e-commerce express delivery volume, which has consistently maintained a barrier level above 17% for years and remains the top obstacle. The second most significant factor is the number of R&D personnel in large-scale industrial enterprises, with its barrier level rising from 12.37% in 2017 to 14.15% in 2024. Cross-border e-commerce enterprise density follows closely, with its barrier level remaining stable at around 11%. This indicates that the scale effect of the logistics system is the most critical bottleneck determining coordination efficiency. Meanwhile, the shortage of high-end R&D talent and market vitality increasingly constrains industrial upgrading, and its negative impacts further propagate, thereby affecting the coupling coordination between the two systems. As show in table 4

Table 4: Ranking of Obstacle Factors in System Indicator Layer of Cross-border E-commerce and Manufacturing Industrial Belt in Eastern China (2017-2024)

Particular Year	Top Factors (%):	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth
2017	barrier indicator	X4	X13	X1	X14	X11	X12	X2	X3
	Degree of impairment	18.02	12.37	10.60	8.53	7.76	6.61	6.55	6.36
2018	barrier indicator	X4	X13	X1	X14	X11	X12	X2	X3
	Degree of impairment	18.17	11.37	10.94	8.48	8.00	6.75	6.64	6.43
2019	barrier indicator	X4	X13	X1	X14	X11	X12	X2	X3
	Degree of impairment	17.66	13.07	10.76	8.35	7.47	6.78	6.43	6.39
2020	barrier indicator	X4	X13	X1	X14	X11	X12	X2	X3
	Degree of impairment	17.00	13.37	10.81	8.11	7.17	6.80	6.48	6.40
2021	barrier indicator	X4	X13	X1	X14	X11	X12	X2	X3
	Degree of impairment	16.91	13.85	10.93	8.02	6.82	6.79	6.58	6.29
2022	barrier indicator	X4	X13	X1	X14	X11	X12	X15	X2
	Degree of impairment	17.44	14.23	11.04	7.88	6.90	6.60	6.14	6.10
2023	barrier indicator	X4	X13	X1	X14	X11	X12	X15	X2
	Degree of impairment	17.86	14.18	11.23	7.76	7.72	6.23	6.10	5.60
2024	barrier indicator	X4	X13	X1	X11	X14	X15	X12	X2
	Degree of impairment	18.28	14.15	11.45	8.61	7.64	6.09	5.82	5.07

4. Conclusions and Recommendations

4.1. Research Findings

(1) The integrated development of cross-border e-commerce and manufacturing industrial clusters in eastern China has shown steady progress, yet significant disparities persist among regions.

(2) While the average coupling coordination degree between cross-border e-commerce and manufacturing industrial clusters in eastern China has transitioned from barely coordinated to initially coordinated, demonstrating positive synergy, most provinces remain at medium-low levels except Guangdong Province which achieved good coordination first. The deep integration of cross-border e-commerce and manufacturing still faces multiple bottlenecks.

(3) The coupling coordination degree of the two systems of cross-border e-commerce and manufacturing industry belt in the eastern region shows strong spatial unbalance, forming a three-level ladder structure.

(4) The obstacle assessment reveals that technological innovation, market scale, and e-commerce logistics constitute the three primary barriers affecting the coupling coordination between cross-border e-commerce and manufacturing industrial clusters in eastern China. Corresponding to these barriers are cross-border e-commerce express delivery volumes, R&D personnel numbers in large-scale industrial enterprises, and the density of cross-border e-commerce businesses. Over time, the growing importance of total labor productivity in large-scale industrial enterprises has become evident.

4.2. Policy Recommendations

(1) To address challenges in technological innovation, market scale, and e-commerce logistics within the cross-border e-commerce and manufacturing industry cluster, targeted solutions should be implemented to overcome collaborative bottlenecks across sectors. Governments should prioritize attracting and nurturing innovative talents through specialized programs for cross-border e-commerce and manufacturing professionals. Both governments and enterprises must optimize the business environment by fostering local benchmark companies and expanding global market reach. Efforts

should also focus on streamlining cross-border logistics systems by leveraging agglomeration effects to reduce costs and enhance efficiency.

(2) Provinces should adopt region-specific strategies to guide coordinated development through categorized approaches. Leading regions like Guangdong should prioritize benchmarking against international standards while promoting high-end sectors such as big data services and supply chain finance. Provinces like Zhejiang and Jiangsu should leverage their distinctive manufacturing clusters and establish e-commerce industrial parks, enabling manufacturers to collectively expand overseas.

(3) Establish and improve long-term cross-regional coordination mechanisms to ensure sustainable development through regional collaboration. High-coordination provinces should expand support to low-coordination regions while consolidating their own development, facilitating the downward transfer of resources and expertise. Low-coordination provinces, while actively learning from others, should focus on developing local manufacturing sectors to identify breakthrough strategies.

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