

## Research on New Quality Productivity Issues in the Digital Age

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### Abstract

**With the acceleration of globalisation, cross-border e-commerce supply chain plays an increasingly important role in China's economy. Against the backdrop of big data, this paper provides an in-depth assessment of the resilience of China's cross-border e-commerce supply chain from 2017 to 2022 using the Coherent Data Envelopment Analysis (CoDEA) methodology, and explores how the new quality of productivity empowers supply chain management in order to improve the overall efficiency and responsiveness to market changes. The study shows that the adaptability and resilience of cross-border e-commerce supply chains have improved significantly through the introduction of advanced information technology and digital tools. We should continue to strengthen the technological infrastructure of cross-border e-commerce supply chains, cultivate talents that meet the needs of new quality productivity, and further enhance the global competitiveness of supply chains through policy incentives and international cooperation.**

### Keywords

**New Quality Productivity; Cross-border E-commerce Supply Chain; Supply Chain Resilience; CoDEA Modeling.**

### 1. Introduction

In the context of big data, the complexity and uncertainty of cross-border e-commerce supply chains are increasing with the advancement of globalisation and the diversification of consumer demands. Therefore, it is particularly important to assess the resilience of cross-border e-commerce supply chains, i.e., their ability to maintain normal operations and recover quickly in the face of various disruptions and shocks.

Cross-border e-commerce supply chain resilience refers to the ability of a supply chain system to adapt and recover in the face of external shocks, risks and uncertainties. It emphasises the resilience and flexibility of supply chains to enable them to cope with challenges and changes, including natural disasters, supply disruptions, fluctuations in market demand, and political instability.

The key to supply chain resilience is the establishment of strong supply chain networks and partnerships, close cooperation and information sharing with suppliers, partners and customers, as well as the establishment of backup suppliers and alternate logistics channels, among other measures, to ensure the sustainability and stability of the supply chain. The development and implementation of risk management and business continuity plans with corresponding preventive and responsive measures can reduce the impact of risks on the supply chain and enable rapid resumption of operations in the event of disruption or disaster.

New-quality productivity is an innovative concept that emphasises the leading role of innovation in productivity development, breaks away from the traditional mode of economic growth and the path of productivity development, and features high-tech, high-efficiency and high-quality advanced productive forces in line with the new development concept. The new quality of productivity is the contemporary advanced productivity spawned by revolutionary breakthroughs in technology, innovative allocation of production factors, and deep transformation and upgrading of industries. It takes the qualitative change of workers, means of labour, objects of labour and their optimal combination as its basic connotation, and the improvement of total factor productivity as its core symbol. This kind of productivity not only embodies a qualitative leap in productivity, but also reflects the new connotation and integrative features of productivity in the digital age.

In this situation, the research on the development status of resilience assessment of China's cross-border e-commerce supply chain under the background of big data and the development of enabling new quality productivity is of great significance, which can help improve the resilience of cross-border e-commerce supply chain and promote the development of new quality productivity.

## 2. Literature Review

The resilience of cross-border e-commerce supply chain refers to the resilience and adaptability of the supply chain in the face of external shocks and challenges. Fan Xuemei, studies the influencing factors of supply chain toughness, and proposes to construct a supply chain toughness evaluation index system from five dimensions of prediction ability, adaptive ability, reactive ability, recovery ability, and learning ability[1]; Qifangzhong constructs a toughness evaluation index system oriented to manufacturing enterprises from the perspective of supply chain, and quantifies the level of toughness by using the improved TOPSIS method, combining the toughness quantitative methods, construct supply chain toughness early warning model[2] ; Chen Qingping's research shows that cross-border e-commerce can significantly improve the toughness of China's exports, especially in response to global market volatility and political risk[3] ; Ma Xiaoyu constructs a research model of supply chain toughness influencing factors, and systematically explores supply chain toughness influencing factors[4] . Christopher and Peck explored the multidimensional nature of supply chain resilience in their paper and emphasised the importance of management strategies in enhancing supply chain resilience[5] . Sheffi's study emphasised the key role of technological innovation in improving supply chain resilience[6] . Wei Zhang et al. used the CoDEA model in their study to assess the resilience and risk transmission of an international trade supply chain under major contingencies, providing a quantitative efficiency and resilience measure for supply chain management[7] ; The aim of the study was to develop a tier-based supply chain resilience model (SCRES) that explains the dynamic relationship between different facilitators, and to validate the model with empirical methods (Jain V , 2017) [8] ; Li Kunwang (2023) analyses the supply chain security of Chinese industries based on the CoDEA method and proposes that a perfect supply chain risk assessment system should be established, which can be referred to measure the resilience level of China's cross-border e-commerce supply chain[9], and make an effective assessment of the supply chain resilience, which is of reference significance to this paper.

Zhou Wen (2023) pointed out that the new quality of productivity is the productivity generated by scientific and technological innovation and key disruptive technological breakthroughs, which is beyond the traditional productivity and requires new production relations to adapt to it[10] . The new quality productivity reflects the advanced productivity qualities of revolutionary technological breakthroughs, innovative allocation of production factors, and

deep transformation and upgrading of industries (Xu Zheng, 2024)[11]. Gu actively promote the exploration of the construction of data base system, better play the important role of data production factors, promote the development of future industries supported by disruptive digital technologies, and cultivate and stimulate the vitality of new quality productivity[12]. New quality productivity supports the intelligent management and optimisation of supply chains, which enhances the efficiency and resilience of supply chains. Xu Wenjing (2024) explored the practical application of new quality productivity in cross-border e-commerce and how to achieve high-quality development through cross-border e-commerce platforms in her study, pointing out that innovation is the key to promoting new productivity and supply chain transformation[13], which is of reference value to this paper on cross-border e-commerce supply chain empowering new quality productivity.2024 The work report of the Chinese government and the Central Economic Work Conference both emphasised scientific and technological innovation as the core, and the necessity of promoting the optimisation and upgrading of the industrial chain supply chain, which not only provides policy support for the resilience of the cross-border e-commerce supply chain, but also points out the direction for the development of new quality productivity (Central Government, 2024). Wang Ruyu (2024) defines and explains the new quality productivity of foreign trade in the spatial reconstruction of the global supply chain, puts forward the viewpoint of its promotion of the high-quality development of foreign trade, and puts forward policy thinking and suggestions[14].

The above literature review shows that the driving role of new quality productivity, the complexity of cross-border e-commerce supply chains and the necessity of improving resilience, as well as the value of the application of the CoDEA methodology in practical assessment, are all important research directions in the current and future fields of supply chain management and technological innovation.

The purpose of studying the assessment of cross-border e-commerce supply chain resilience, influencing factors and empowering new quality productivity is to understand the current status of China's cross-border e-commerce supply chain resilience and security, as well as the impact on new quality productivity, and in the future when facing the risk of cross-border e-commerce supply chain, to provide ideas, put forward optimisation suggestions for China's cross-border e-commerce supply chain to cope with the risk from different nodes, strengthen the resilience of the whole supply chain, and provide useful help and inspiration for China's cross-border e-commerce production capacity and productivity of China's cross-border e-commerce, provide useful help and inspiration, and empower the development of China's new quality productivity.

### **3. The Current Situation of Cross-border E-commerce Supply Chain**

Under the background of global integration and big data, cross-border e-commerce has become a powerful "booster" for China to expand its international market and develop its export-oriented economy. The cross-border e-commerce supply chain is undergoing the reconstruction and reshaping of the global supply chain, and the resilience of the cross-border e-commerce supply chain is increasing, showing trends of intelligence, collaboration, greening and localisation, etc.; the following is an analysis of the current situation of the development of cross-border e-commerce supply chain:

#### **3.1. Regionalisation of Cross-border E-commerce Supply Chain Localisation**

In order to cope with the challenges of the global economic downturn and weak demand in overseas markets, China's cross-border e-commerce companies are accelerating the reconstruction and reshaping of the global supply chain system; seeking breakthroughs in global supply chain management, overseas network infrastructure construction, and overseas localised operations to ensure that they can gain an advantage in the global competition;

localising products, localising brands, localising supply chain management, and localising operations, reducing operating costs and Improve logistics efficiency and satisfy consumer demand to a greater extent; integrate supply chain resources globally, and at the same time localise operations according to local market demand and cultural differences; establish local infrastructure such as warehouses and distribution centres to achieve rapid response and localised services, and improve the adaptability and resilience of the supply chain; and enhance market responsiveness and competitiveness.

### **3.2. Cross-border E-commerce Supply Chain Collaboration and Integration**

In order to cope with the complexity of the risk challenges, cross-border e-commerce supply chain focuses on supply chain synergy and integration, establishes closer cooperation with suppliers, logistics providers, e-commerce platforms and other partners, realises seamless docking and efficient collaboration between various links, and achieves information sharing and optimal allocation of resources by integrating supply chain resources, information sharing, collaborative decision-making, joint purchasing, etc. , enhance the overall efficiency and competitiveness of the supply chain, reduce logistics costs, improve logistics efficiency, achieve optimisation and synergy of cross-border e-commerce supply chain, and enhance the adaptability and resilience of cross-border e-commerce. The cross-border e-commerce supply chain involves multiple links and multiple participants, and it needs to strengthen the synergy and cooperation in order to improve the resilience of the whole supply chain. More and more enterprises are beginning to strengthen the synergy and cooperation between supply chain partners to jointly address the risks and challenges in the supply chain.

### **3.3. Digital Intelligence in Cross-border E-commerce Supply Chains**

The level of digital intelligence in cross-border e-commerce supply chain is constantly improving, and the intelligent management and optimisation of the supply chain is achieved through the introduction of advanced technologies such as artificial intelligence, big data, etc., which provide important support for the resilience and competitiveness enhancement of cross-border e-commerce supply chain, e.g., the application of technologies such as logistics tracking system, intelligent warehouse management, and drone delivery. By collecting and analysing massive consumer data, transaction data, logistics data, etc., enterprises can more accurately grasp market demand, optimise inventory management, reduce operating costs, improve logistics efficiency, and more accurately predict and respond to risks and challenges in the supply chain.

### **3.4. Cross-border E-commerce Supply Chain Complexity**

The complexity of cross-border e-commerce supply chain increases, with the rapid development of cross-border e-commerce, the complexity of the supply chain is also increasing, which is mainly manifested in the increase of links in the supply chain, the increase in the number of participants, the complexity of the flow of information, and the complexity of the risk transmission, etc., the various participating countries in the international trade supply chain network at different nodes may act as both upstream and downstream nodes at the same time, and this high level of interactivity and integration makes the risk transmission This high degree of interaction and integration makes the risk transmission process extremely complex, and the risk is no longer simply transmitted in a single direction (e.g., only to the downstream or upstream nodes), but forms a continuous cross-circulation transmission process. This complexity creates challenges for supply chain management and coordination, but also offers the possibility of supply chain resilience. Through resilience-based analysis, the transmission mechanism of risk in the supply chain network can be better understood, providing strong support for optimising risk management strategies and promoting the sustainable development of supply chains.

### 3.5. Sustainable Development of Cross-border E-commerce Supply Chains

With the improvement of environmental awareness and the popularisation of the concept of sustainable development, cross-border e-commerce supply chains will pay more attention to green and sustainable development. By adopting environmentally friendly materials, reducing packaging waste and promoting green logistics, it will reduce the environmental impact of the supply chain, while improving the sustainability and resilience of the supply chain; and by optimising the structure of the supply chain network and enhancing the resilience of the supply chain, it will promote the sustainable development of the supply chain, making it more robust and flexible in the face of various uncertainties and challenges.

## 4. Assessment of Cross-border E-commerce Supply Chain Resilience based on CoDEA Model

### 4.1. Data Sources

The data used in this paper is selected from 2017-2022 there is data on cross-border e-commerce, as shown in Table 1.

**Table 1.** Data related to cross-border e-commerce, 2017-2022

norm vintages	2017	2018	2019	2020	2021	2022
China's exports of goods (billions of dollars)	23000	25,000	25,000	26000	34000	36000
Market size of China's cross-border export e-commerce industry (RMB billion)	22000	28000	37000	46000	60,000	66000
Platform turnover (billions of dollars)	57903	57189	54278	50436	47311	41656
Import cross-border e-commerce user scale (billion)	0.66	0.885	1.25	1.4	1.55	1.68
Cross-border e-commerce logistics market size (billion yuan)	62942.77	67004.95	71700.9	77378.28	87001	82651

(Source: IGES, NSO).

### 4.2. Research Methodology

Coherent Data Envelopment Analysis (hereafter referred to as "CoDEA") is a state-of-the-art assessment method, which extends the traditional Data Envelopment Analysis (DEA) by focusing on the coherence and dependency between different nodes in the supply chain. It extends on the traditional Data Envelopment Analysis (DEA), with special emphasis on the coherence and dependency between different nodes in the supply chain. As shown in Figure 1, CoDEA cleverly introduces a virtual intermediate measure compared to the traditional DEA approach and successfully maximises network efficiency in the final stage. By simulating the actual operation process of the supply chain, this approach not only considers the input-output efficiency of each node, but also places it in the context of the whole supply chain network for analysis.

The importance of CoDEA in supply chain management cannot be overstated. It provides a unique perspective to assess the resilience of a supply chain. Resilience refers to the ability of a supply chain to maintain its functionality and performance in the face of internal and external shocks. By using CoDEA, managers can gain insights into the efficiency levels of individual nodes in the supply chain and how these nodes depend on and influence each other, thereby identifying potential vulnerabilities and bottlenecks.

Coherent Data Envelopment Analysis (CoDEA) is a powerful and practical tool whose utility lies in its ability to quantify the resilience of a supply chain and provide specific recommendations for improvement. By calculating the network efficiency of a supply chain, managers can clearly see which nodes have the greatest impact on the overall efficiency and how to improve the resilience of the entire supply chain by optimising the efficiency of these nodes, providing managers with a new way to gain insight into and improve the supply chain, thus enhancing its adaptability and stability. In addition, CoDEA is able to simulate supply chain performance under different scenarios, helping managers to predict and respond to potential risks and challenges.

In cross-border e-commerce supply chains, the application of CoDEA (Coherent Data Envelopment Analysis) methods can effectively analyse and improve the resilience and efficiency of the entire supply chain.

The methodology is particularly suitable for assessing the network structure of a cross-border e-commerce supply chain, where we represent the three main key components of a cross-border e-commerce supply chain with these data: the producer (Exporter, Exporter), the export intermediary (Logistics and transport sector, Logistics and transport sector, and sales platform, Sales platform) and the consumer (Importer, Importer). Sales platform) and the consumer (Importer, Importer).

As shown in Figure 2, the flowchart reveals how the CoDEA method analyses the relationship between e-commerce suppliers, logistics service and sales platform providers, and end consumers to derive the efficiency of the cross-border e-commerce supply chain.

Firstly, cross-border e-commerce suppliers act as producers and suppliers of products, playing the role of exporters, responsible for manufacturing and preparing goods suitable for cross-border sales. In this segment, the CoDEA method evaluates the supplier's production efficiency and analyses the relationship between its production inputs (e.g., materials, labour costs, etc.) and outputs (quantity and quality of finished products). By accurately measuring supplier efficiency, potential opportunities to enhance production processes and reduce costs can be identified.

Next, logistics service providers and sales platforms play a key role in the cross-border e-commerce supply chain to undertake and transit goods, which includes the entire logistics process from suppliers to consumer markets. In this segment, the CoDEA model evaluates the inputs and outputs of the transport and warehousing process by analysing the logistics efficiency. The efficiency of the logistics link directly affects the speed and cost of product distribution, which in turn affects the efficiency of the entire supply chain.

Finally, the e-commerce platform and end-consumer segment involves the final sale and distribution of goods. The CoDEA methodology is applied at this stage by taking the efficiency of the first two segments as inputs and combining them with the direct inputs of the e-commerce sale such as marketing and customer service to assess how efficiently the goods can be distributed to consumers.

By integrating efficiency data from each link, the CoDEA model not only shows the performance of individual links, but also reveals how the links interact with each other to shape the resilience of the entire supply chain. This chain-wide efficiency assessment provides valuable insights into e-commerce supply chain management, helping companies to identify key performance bottlenecks, optimise operational strategies, and ultimately achieve cost savings and service optimisation. In today's increasingly competitive global marketplace, using the CoDEA methodology to improve supply chain resilience and efficiency is especially critical to maintaining market competitiveness and addressing various external challenges.

### 4.3. Research Process

#### 4.3.1. Model Construction

The CoDEA model consists of a set of formulas and constraints for calculating the efficiency of a supply chain decision making unit (DMU), considering both inputs and outputs, and the model functions used in this paper are as follows:

Efficiency ratio ( $\theta$ ).

$$\theta = \frac{\sum_{r=1}^s \mu_r Y_r}{\sum_{i=1}^m v_i X_i} \tag{1}$$

**Table 2.** Interpretation of parameters of efficiency ratios

parametric	account for
$\mu_r$	Output ( $Y_r$ ) Weights assigned
$v_i$	The input ( $X_i$ ) assigned weights
$Y_r$	Output of supply chain nodes
$X_i$	Inputs from supply chain nodes

This formula calculates the efficiency ratio by comparing the weighted sum of the outputs to the weighted sum of the inputs.

Minimising inefficient objective functions: the

$$\theta - e(\sum_{i=1}^m s_i^- + \sum_{r=1}^s s_r^+) \tag{2}$$

**Table 3.** Explanation of the parameters of the objective function for minimising inefficiency

parametric	account for
$s_i^-$	Input slack variables representing redundant inputs that can be reduced
$s_i^+$	Output slack variable representing the output shortage that needs to be increased
$e$	A small positive number to ensure strict positivity in the model

This optimisation aims to minimise inefficiencies by reducing unnecessary inputs and increasing required outputs.

Binding:

$$\sum_{j=1}^n \lambda_j X_{ji} + s_i^- = \theta X_{i0}, \quad i = 1, \dots, m \tag{3}$$

$$\sum_{j=1}^n \lambda_j Y_{jr} - s_r^+ = Y_{r0}, \quad r = 1, \dots, s \tag{4}$$

$\lambda_j$ : Coefficients representing DMU strengths. The constraint ensures that the inputs and outputs are aligned with the actual data after considering the inefficiency adjustment.

The improved CoDEA model quantifies the efficiency of each supply chain node and identifies efficiency bottlenecks in the supply chain by optimising the ratio between inputs and outputs. Below is the mathematical expression of the model and the specific meaning of its parameters.

Objective function:

$$\min \Phi - e(\sum_{i=1}^u s_i^+ + \sum_{t=1}^p z_t^+ + \sum_{r=1}^v s_r^+) \tag{5}$$

**Table 4.** Explanation of the parameters of the objective function

parametric	account for
$\Phi$	Overall supply chain efficiency
$e$	Positive fine-tuning parameters for mathematical stability and non-negativity of the model
$s_i^+$	Excess (wasted portion) of the $i$ th input variable
$z_t^+$	Non-efficiency component of the $t$ th process variable
$s_r^+$	Insufficiency of the $r$ th output variable

Input constraints:

$$\sum_{j=1}^h \rho_j X_{ij} + s_i = \Phi X_{i0}, \quad i = 1, \dots, u \tag{6}$$

**Table 5.** Explanation of input constraint parameters

parametric	account for
$\rho_j$	The first $j$ Weights of decision-making units
$X_{ij}$	The first $i$ The inputs in the first $j$ of the decision unit
$X_{i0}$	The first input of the base decision unit $i$ The first input to the base decision unit
$s_i$	The first $i$ slack variable for the first input, indicating that the input wasted

Process constraints:

$$\sum_{j=1}^h \rho_j \theta_{jt} + z_t = \Phi \theta_{t0}, \quad t = 1, \dots, p \tag{7}$$

**Table 6.** Explanation of process constraint parameters

parametric	account for
$\theta_{jt}$	Performance of the $j$ decision module in the $\theta_{t0}$ process
$\theta_{t0}$	Benchmarking $j$ th process performance of the policy unit
$z_t$	The amount of inefficiency in the $t$ th process

Output constraints:

$$\sum_{j=1}^h \rho_j Y_{jr} - s_r = Y_{r0}, \quad r = 1, \dots, v \tag{8}$$

**Table 7.** Explanation of output constraint parameters

parametric	account for
$Y_{jr}$	No. $j$ The first output of the decision unit $r$ Output
$Y_{r0}$	The first output of the base decision unit $r$ Output
$s_r$	The first $r$ Insufficiency of the first output

### 4.3.2. Analytical Process

(1) Input constraints

This formula is used to assess the input efficiency of each node in the supply chain and is a typical Data Envelopment Analysis (DEA) model.

$$\sum_{j=1}^h \rho_j X_{ij} + s_i = \Phi X_{i0}, \quad i = 1, \dots, u \tag{9}$$

**Table 8.** Explanation of input constraint parameters

parametric	account for
$\rho_j$	The first $j$ Weights of decision-making units
$X_{ij}$	The first $i$ The inputs in the first $j$ of the decision unit
$X_{i0}$	The first input of the base decision unit $i$ The first input to the base decision unit
$s_i$	The first $i$ slack variable for the first input, indicating that the input wasted

The formula considers the input variables of each decision unit and their efficiency. In this case, we can apply this formula to cross-border e-commerce with user size as an input to assess its efficiency.

For cross-border e-commerce, we can consider user size as an input, while the output can be platform transaction volume or market size. Here, we assume that each year is a separate decision unit and assess efficiency using user size as input and platform transaction volume as output. With each year's data as a decision unit, we calculate the efficiency from 2017 to 2022:

Input (X) data: Import cross-border e-commerce user size

Output (Y) data: platform turnover

To simplify the calculations, we temporarily assume that the weight ( $\rho_j$ ) of each decision unit is 1 and that no input slack variables are taken into account (i.e., assuming  $S_i = 0$ ), then Eq. simplifies to:

$$X_i = \Phi X_{i0} \tag{10}$$

Here we tentatively assume that the base year ( $X_{i0}$ ) is 2017 data.

Using 2017 data as the 3 benchmark, calculate the efficiency from 2018 to 2022. Benchmark input  $X_{2017} = 0.66$ , output  $Y_{2017} = 5790$ .

$$\begin{aligned} \Phi_{2018} &= \frac{X_{2018}}{X_{2017}} = \frac{0.885}{0.66} \approx 1.34 \\ \Phi_{2019} &= \frac{X_{2019}}{X_{2017}} = \frac{1.25}{0.66} \approx 1.89 \\ \Phi_{2020} &= \frac{X_{2020}}{X_{2017}} = \frac{1.4}{0.66} \approx 2.12 \\ \Phi_{2021} &= \frac{X_{2021}}{X_{2017}} = \frac{1.55}{0.66} \approx 2.35 \\ \Phi_{2022} &= \frac{X_{2022}}{X_{2017}} = \frac{1.68}{0.66} \approx 2.55 \end{aligned}$$

The calculations show that from 2017 to 2022, the user size input efficiency of cross-border e-commerce shows a growing trend. This means that each year's user growth has exceeded the 2017 level, showing the growth efficiency of cross-border e-commerce platforms in expanding their user base. This growth could be driven by factors such as market expansion, successful implementation of marketing strategies, etc.

(2) Process constraints

Used to assess process efficiency in cross-border e-commerce supply chains. It measures the contribution of different operations or stages to overall efficiency.

$$\sum_{j=1}^h \rho_j \theta_{jt} + z_t = \Phi \theta_{t0}, \quad t = 1, \dots, p \tag{11}$$

**Table 9.** Explanation of process constraint parameters

parametric	account for
$\theta_{jt}$	Performance of the j decision module in the $\theta_{t0}$ process
$\theta_{t0}$	Benchmarking jth process performance of the policy unit
$z_t$	The amount of inefficiency in the tth process

Here, we can analyse the efficiency of transaction processing each year by using the platform transaction volume as a process variable ( $\theta_{jt}$ ).

Set each year as a decision unit and use platform transactions to calculate process efficiency for each year relative to 2017.

Assume 2017 as the base year,  $\theta_{2017} = 579.03$  billion, and the weights ( $\rho_j$ ) of all decision units are assumed to be 1 to simplify the calculation. Assume that there is no significant amount of inefficiency  $z_t = 0$ , i.e., all transactions are efficient. Using 2017 as the baseline, the efficiency is calculated for 2018-2022.

$$\begin{aligned} \Phi_{2018} &= \frac{57189}{57903} = 0.9875 \\ \Phi_{2019} &= \frac{54278}{57903} = 0.9373 \\ \Phi_{2020} &= \frac{50436}{57903} = 0.8709 \\ \Phi_{2021} &= \frac{47311}{57903} = 0.8170 \\ \Phi_{2022} &= \frac{41656}{57903} = 0.7194 \end{aligned}$$

Based on the calculations, it can be seen that the efficiency of cross-border e-commerce platforms in terms of transaction processing is on a downward trend from 2018 to 2022 relative to 2017. This suggests that while platforms may be increasing their users and market size, their efficiency in converting this growth into transactions is declining. This decline may be related to market saturation, increased competition, or declining internal operational efficiency.

This decline in efficiency requires further attention and analysis to determine the reasons behind it and take steps to improve it. Cross-border e-commerce platforms may need to optimise their user conversion strategies, increase the attractiveness of their platforms or improve the user experience in order to increase transaction efficiency and overall supply chain resilience.

**(3) Output constraints**

In order to analyse the resilience of cross-border e-commerce supply chains in China, we will use the output constraint formula, where  $Y_{jr}$  denotes the actual performance of the jth decision unit on the rth output,  $Y_{r0}$  is the target (or desired) output, and  $s_r$  represents the slack variable of the rth output, which indicates the gap between the actual output and the target output.

$$\sum_{j=1}^h \rho_j Y_{jr} - s_r = Y_{r0}, \quad r = 1, \dots, v \tag{12}$$

**Table 10.** Explanation of output constraint parameters

parametric	account for
$Y_{jr}$	No. $j$ The first output of the decision unit $r$ Output
$Y_{r0}$	The first output of the base decision unit $r$ Output
$s_r$	The first $r$ Insufficiency of the first output

Based on the data from previous years, we can assume the variables used in the following analyses:

$Y_{jr}$  can represent China's goods export value, cross-border export e-commerce industry market size, and platform transaction volume for each year, which reflect the output performance of the supply chain.

$Y_{r0}$  will be set to the maximum value of each output metric over the observation period as the desired optimal output level.

$s_r$  The difference between what would be calculated as  $Y_{r0}$  and the actual  $Y_{jr}$  would indicate the gap between the indicators not achieving optimal performance in each year.

To simplify the example, we only consider "China's exports of goods" as an output indicator, as shown in Table 11.

**Table 11.** Output indicators (in billions)

vintages	China's exports of goods
2017	23000
2018	25,000
2019	25,000
2020	26000
2021	34000
2022	36000

Assuming that  $Y_{r0}$  (the desired optimal output) is 36,000 billion, we can calculate the annual  $s_r$  :

**Table 12.** Relaxation variables for the  $r$ th output

vintages	$s_r$ (be) worth
2017	36000-23000=13000
2018	36000-25000=11000
2019	36000-25000=11000
2020	36000-26000=10000
2021	36000-34000=2000
2022	36000-36000=0

The analyses show that China's cross-border e-commerce supply chain displays a gradual increase in resilience in terms of the value of goods exported from 2017 to 2022. The slack variables  $s_r$  decrease indicates that the supply chain tends to be more optimised and robust in response to external changes (e.g. market demand, international trade policies, etc.) year by year. By 2022, the value of goods exported has reached the set optimal level, demonstrating extreme resilience and excellent market adaptability.

(4) Resilience assessment

Based on the objective function and related data, we can conduct an analysis to assess the resilience of cross-border e-commerce supply chains in China from 2017 to 2022. The objective

function aims to minimise the inefficiency factor, which is achieved by reducing unnecessary inputs, process losses and outputs that are not achieved.

$$\min \Phi - e(\sum_{i=1}^u s_i^+ + \sum_{t=1}^p z_t^+ + \sum_{r=1}^v s_r^+) \tag{13}$$

To simplify the analysis, we assume that there is no significant amount of excess or deficiency ( $s_i^+ = 0, z_t^+ = 0, s_r^+ = 0$ ) and set  $e$  to a small positive number such as  $e = 0.01$ .

**Table 13.** Data used for the efficiency function (in billions)

vintages	Import cross-border e-commerce user size (X)	Platform turnover (Z)	Sum of exports and market size (Y)
2017	0.66	57903	45,000
2018	0.885	57189	53000
2019	1.25	54278	62000
2020	1.4	50436	72000
2021	1.55	47311	94000
2022	1.68	41656	102000

Assuming that the outputs and inputs and processes are perfectly efficient, we calculate the annual efficiency as:

$$\Phi = \frac{Y}{X+Z} \tag{14}$$

$$\Phi_{2017} = \frac{45000}{0.66 + 57903} \approx 0.776$$

$$\Phi_{2018} = \frac{53000}{0.885 + 57189} \approx 0.926$$

$$\Phi_{2019} = \frac{62000}{1.25 + 54278} \approx 1.141$$

$$\Phi_{2020} = \frac{72000}{1.4 + 50436} \approx 1.424$$

$$\Phi_{2021} = \frac{94000}{1.55 + 47311} \approx 1.985$$

$$\Phi_{2022} = \frac{102000}{1.68 + 41656} \approx 2.446$$

The analysis shows that the efficiency of China's cross-border e-commerce supply chain improved significantly from 2017 to 2022. The improved efficiency indicates that supply chains have become more responsive to market movements, are able to utilise resources more efficiently, reduce waste, and increase output. This successive years of efficiency improvement demonstrates the resilience of supply chains to adapt and withstand external economic fluctuations and market pressures, and continue to optimise their operations and management.

## 4.4. Findings

Combining these four research processes, we can see several key trends and results in the analysis of cross-border e-commerce supply chain resilience from 2017 to 2022, as shown in Figure 5:

### 4.4.1. Input Efficiency Improvement

The year-on-year increase from 1.34 in 2017 to 2.55 in 2021 shows a continuous improvement in input efficiency, indicating that the cross-border e-commerce supply chain is becoming more and more efficient in its use of resources. Taking 2022 as a benchmark, it is clear that supply chain management is being gradually optimised from 2017 to 2021, both in terms of improved input efficiency, adjustments in process efficiency, and significant growth in objective function efficiency, pointing to the success of effective management and technology application. Moreover, this continuous progress may also be linked to factors such as the application of new technologies, changes in the market environment and policy support.

### 4.4.2. Fluctuations in Process Efficiency

Process efficiencies begin to decline slightly from 0.9875 in 2017 to 0.7194 in 2021, suggesting that despite input efficiency gains, certain intermediate processes in the supply chain may have efficiency losses or operational challenges.

### 4.4.3. Stable Growth in the Efficiency of the Objective Function

It shows a year-on-year increase from 0.776 in 2017 to 2.446 in 2022, suggesting that cross-border e-commerce supply chains are becoming more effective in reaching their intended goals, which may reflect improved internal management or a more optimised supply chain structure.

### 4.4.4. Output Slack Variables

The reduction of the variable from 1,300 in 2017 to 200 in 2021 and then to 0 in 2022 shows that the cross-border e-commerce supply chain has made significant progress in managing excess resources, especially in the most recent year when it reached an optimal state.

To summarise, China's cross-border e-commerce supply chain resilience shows significant improvements between 2017 and 2022, particularly in terms of efficient use of resources and effective achievement of targets. However, fluctuations in process efficiency are a reminder of the continued need to focus on and optimise the intermediate stages of the supply chain to ensure that each step is as efficient as possible. Policymakers and industry practitioners can consider these trends to further enhance supply chain management, especially in terms of big data and technology integration, to empower the development of new qualitative productivity and improve overall economic efficiency.

## 5. Conclusion and Suggestions

### 5.1. Conclusion

An assessment of supply chain resilience in China's cross-border e-commerce (2017-2022): According to the statistical measurements of the CoDEA model and related data analysis, the resilience of China's cross-border e-commerce supply chain increased significantly between 2017 and 2022. This trend is reflected in several key aspects:

#### 5.1.1. Increased Efficiency of Supply Chain Output

The data shows that the country's exports of goods are growing year on year as the year progresses, especially in 2022 when it reaches an optimal output of \$3,600bn, demonstrating that the supply chain has become significantly more efficient in achieving its economic goals.

### 5.1.2. Increased Adaptability and Resilience

Supply chains have demonstrated greater adaptability and resilience in the face of fluctuating global market demand, trade policy adjustments and other external economic pressures. Especially in the face of global challenges such as the COVID-19 outbreak, the supply chain was able to quickly adjust its strategy to ensure continuity and efficiency of operations.

### 5.1.3. Technology Integration and Application Optimisation

The widespread use of information technology and digital solutions such as AI, IoT, and big data analytics has become a key driver in improving supply chain resilience, with these technologies helping organisations to more accurately anticipate market changes, optimise inventory management, and improve logistics efficiency.

## 5.2. Suggestions

Strategies for empowering new quality productivity:

### 5.2.1. Scientific and Technological Innovation and Industrial Upgrading

Continuous investment in key technologies, especially in the research, development and application of digital and intelligent technologies. At the policy level, as stated in the 2024 Government Work Report, the construction of a modernised industrial system should be vigorously promoted, industrial upgrading should be led by scientific and technological innovation, and the development of new-quality productivity should be accelerated. This involves not only the support of high-tech industries, but also the technological transformation and upgrading of traditional industries.

### 5.2.2. Industry Chain Synergy and Integration

Establish a closer cooperation mechanism between the various links in the supply chain to improve the responsiveness and flexibility of the overall supply chain by integrating resources and sharing information. The Government and the industry should jointly promote cross-regional and cross-industry supply chain integration projects to strengthen the structure of the supply chain and enhance its global competitiveness.

### 5.2.3. Talent Training and Educational Innovation

In accordance with the strategy of "revitalising the country through science and education", investment in education and human resources training has been increased, especially in the areas of supply chain management and the application of emerging technologies, so as to cultivate complex human resources capable of adapting to the needs of the new quality of productive forces. Collaboration between higher education and industry will be strengthened to promote closer integration of vocational education with industry needs.

### 5.2.4. Policy Support and Incentives

The Government should continue to introduce policies favourable to the development of new quality productivity, such as tax incentives and financial support for innovation, especially in support of new forms of trade such as cross-border e-commerce. At the same time, policy coordination and trade facilitation in domestic and foreign markets should be strengthened to create a more favourable international trade environment for cross-border e-commerce.

Through the above measures, not only can we enhance the resilience of China's cross-border e-commerce supply chain, but also strengthen its competitiveness in the global market, and at the same time, drive through science and technology and innovation to realise a qualitative leap in productivity, and inject new impetus into the country's economic development.

## Acknowledgments

This research was supported by Anhui University of Finance and Economics Student Innovation and Entrepreneurship Training Programme Project (202410378257).

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