ISSN 2959-6130

Empirical analysis of the development relationship between Shanghai shipping industry and primary industry based on VAR model

Tianjie Zhang

Computer Science, Shanghai Maritime University, Shanghai, 201306, China
Email: 202310310226@stu.shmtu.edu.cn

Abstract:

This study employs the Vector Autoregression (VAR) model to conduct an in-depth empirical analysis of the dynamic relationship between Shanghai's shipping industry and the development of the primary sector from 2002 to 2022. The findings reveal that, as a globally significant maritime hub, the development of Shanghai's shipping industry has a notable positive impact on the growth of the primary sector, particularly in agriculture and fisheries. Through ADF unit root tests, cointegration tests, and Granger causality tests, a stable long-term relationship was identified between shipping industry indicators, such as container throughput and total waterborne cargo transport volume, and the output value of the primary sector. Impulse response analysis and variance decomposition further reveal the critical roles and mechanisms through which the shipping industry influences the development of the primary sector. Based on these insights, the paper proposes policy recommendations aimed at strengthening the integrated development of shipping and the primary sector, promoting technological innovation in the shipping industry, optimizing the policy environment, enhancing environmental protection measures, and bolstering international cooperation. These strategies are intended to foster synergistic development between the two sectors and drive sustainable economic growth.

Keywords: VAR model, Shipping Industry, Primary Sector, Empirical Analysis

1. Introduction

In the context of a globalized economy, the shipping industry serves as a critical linchpin connecting world markets, with a profound impact on regional economies, particularly on the development of the primary sector. Shanghai, home to one of the world's largest ports, plays a pivotal role in global trade and the Chinese economy. The Port of Shanghai's throughput has consistently ranked first in the world for several consecutive years, exerting a significant influence on goods transportation and trade flows, both within China and globally. [1] The primary sector, especially agricultural production, is crucial for the stability and development of regional economies. Despite not being the dominant industry in Shanghai, an essential economic hub, it still plays a vital role in ensuring food security and promoting rural economic development.[2] As a critical logistics and transportation sector, the shipping industry has a significant impact on the export and inland transportation of products from the primary sector. With economic development and industrial restructuring, both the primary sector and the shipping industry in Shanghai are undergoing continuous changes. The development of the shipping industry not only affects the flow of goods and resources but also indirectly influences the development of the primary sector. This reflection aims to articulate the intricate and dynamic relationship between these sectors with precision and eloquence.

2. Literature Review

Recent years have seen widespread attention on the relationship between various industries and the development of the primary sector. Domestically, researchers have focused on the specific development of the primary sector in regions and its interaction with other economic factors. In 2023, David Feng's study, employing multivariate regression analysis, delved into the relationship between Hainan's logistics industry and its primary sector, examining indicators such as transportation, warehousing, postal services, output, and turnover volume. This analysis correlated these indicators with Hainan's GDP to highlight the significance of the logistics industry for the primary sector's development.[3] Chunfang Zhang (2016) applied multivariate regression models to empirically analyze the development of Hebei's primary sector during the "Thirteenth Five-Year Plan," revealing factors affecting its development by analyzing agricultural machinery power, grain production, and non-agricultural employment.

[4]Chong Tang (2012) explored China's primary sector economic development using panel data, examining the impact of capital, labor, and land inputs on the GDP of the primary sector, providing insights into the economic dynamics of China's primary sector.[5]
Internationally, Gaydin Sergey's (2016) research on shipping and fisheries in Yenisei Province from the late 19th to the early 20th century demonstrated how these industries jointly promoted the development of fishing and hunting, enhancing efficiency and market relations, and advancing the regional fishing and hunting industry. [6]Paul Tae-Woo Lee, Oh Kyoung Kwon, and Xiao Ruan (2019) focused on sustainability issues in maritime shipping, ports, and maritime logistics, highlighting the importance of sustainability, which gained prominence with increased regulation by the International Maritime Organization since 1997, fostering a wealth of academic work.[7]
These studies, while focusing on the development of the primary sector in specific regions and its impact from logistics, agricultural machinery, grain production, fishing and hunting, and sustainability, do not extensively explore the specific connection between the shipping industry and the primary sector, indicating a gap in the research.
Furthermore, research on the relationship between the shipping industry and the development of other industries, both domestically and internationally, showcases diversity and depth, with recent focuses on digitalization, environmental impact, and economic efficiency of the shipping industry. Domestically, Sun Yimeng, Fan Hongbo, Peng Manyu, and Zhuang Jinyu (2023) highlighted the potential application of blockchain technology in the shipping industry, especially in port logistics, proposing a blockchain-based port logistics transaction data sharing architecture to optimize shipping business processes.[8] Zhang Haibo, Wu Chengjie, and Liu Zhige (2023) discussed the shipping industry's emission reduction challenges under China's dual carbon goals, exploring the key role of clean energy in transitioning from low to zero carbon emissions, emphasizing green transformation as the future development direction under environmental policy guidance.[9]
Internationally, Xiaoxuan Zhou, Lei Dai, Hao Hu, and Mingyang Zhang (2024) focused on the economic viability and CO_2 emissions in the shipping industry under the Maritime Emission Trading System (METS), revealing METS's potential to reduce CO_2 emissions in the short term but possibly increasing overall emissions, highlighting the need to balance economic benefits and emission efficiency in emission trading policy formulation. [10] Dimitrios Parris, Konstantinos Spinthiropoulos, Konstantina Ragazou, Vasileios Kanavas, and Constantinos Tsanaktsidis (2023) innovatively assessed the ecological efficiency of the global shipping industry, using dynamic slack-based non-oriented Data Envelopment Analysis and visualizing results with ArcGIS, finding varying ecological efficiencies across major shipping regions, with traditional maritime economies like China showing significant improvement due to the adoption of environmental, social, and governance principles.
In summary, these studies from various angles showcase the complex relationship between the shipping industry and other industries, involving technological innovation, environmental protection, and economic efficiency, reflecting the development dynamics of the shipping industry in globalization and environmental trends. However, they do not deeply explore the relationship between the shipping industry and the development of other industries. [11]
Thus, this paper focuses on analyzing the interaction between the shipping industry and the primary sector in Shanghai, a crucial global shipping center. This perspective is relatively rare in existing literature, offering insights into the relationship between the shipping industry and the primary sector. By employing the VAR model, this study not only provides new insights into the economic effects of the shipping industry on agriculture, fisheries, and other primary sectors but also supports policy-making, offering a fresh perspective for academic research and practical application in this field.

3. Research Methodology

This study employs the Vector Autoregression Model (VAR model) as the primary analytical tool to explore the dynamic relationship between the development of Shanghai's shipping industry and the primary sector. The VAR model is a statistical approach designed to analyze the intrinsic dynamic relationships among multiple time series data.[12] It examines the linear dependencies of each variable on its own past values and those of other variables, thereby uncovering the mutual influences between variables. The VAR model is particularly well-suited to the needs of this study for several reasons:
1.Multivariate Analysis Capability: The VAR model can handle multiple economic time series data simultaneously, making it exceptionally applicable for analyzing the interactions and feedback mechanisms between Shanghai's shipping industry and the primary sector. This multivariate approach enables a comprehensive examination of the complex interplay between the two sectors, rather than merely assessing one-way influences.
2.Dynamic Relationship Capture: Since the VAR model is grounded in time series data, it adeptly captures the dynamic relationships between economic variables over time. This is ideal for exploring the evolving interactions

between the shipping industry and the primary sector.

3.Causality Analysis: Through methods such as the Granger causality test, the VAR model facilitates the identification of potential causal relationships between variables. This provides a robust theoretical basis for informed policy-making.

4.Impulse Response Analysis and Variance Decomposition: A significant advantage of the VAR model is its capability to conduct impulse response analysis and variance decomposition. These methods aid in understanding how one variable reacts to the shock of another and the sources of fluctuations in variables, further deepening insights into the interactive relationship between the shipping industry and the primary sector.

4. Data Sources and Processing

The data for this study primarily come from government statistical data, official economic reports, and industry-related literature. Specifically, data related to the shipping industry, such as total waterborne cargo transport volume in Shanghai, total import and export volume of Shanghai, container throughput in Shanghai, and changes in the CCFI composite index by the end of July, will be collected from the Shanghai Municipal Government, the National Bureau of Statistics, the Shanghai Shipping Exchange, and industry-related literature. Additionally, data on the Gross Domestic Product (GDP) of Shanghai's primary sector will also be collected. The timeframe for these data spans from 2002 to 2022, ensuring the timeliness and accuracy of the analysis.

In terms of data processing, the first step involves data cleaning to exclude incomplete, inaccurate, or anomalous data. Subsequently, the data will be standardized to eliminate the impact of different scales and ensure comparability between different indicators.

5. Model Construction

5.1 *Selection of Indicators and Data:*

① For the primary sector, this paper selects the Gross Domestic Product (GDP) of Shanghai's primary sector, hereafter referred to as Firstindustry, as the dependent variable.

② In terms of the shipping industry, considering data availability and practicality, this study selects the following four variables as independent variables: total volume of waterborne freight in Shanghai (Trans), total import and export volume of Shanghai (Openness), container throughput of Shanghai (Container), and the China Container Freight Index at the end of July (CCFI).

Openness represents the total value of all import and export activities conducted through Shanghai, calculated as the sum of the value of all imported and exported goods through Shanghai over a certain period.

5.2 *Model Establishment:*

A typical VAR model is expressed as: $\mathrm{SPITO} = \beta 0 + \beta 1 X1 + \beta 2 X2 + \cdots + \beta n Xn + \epsilon$. Based on the multivariate regression model, the general formula is set, where $\mathrm{Y_t = A_0 + A_1 Y_{t-1} + A_2 Y_{t-2} + L + A_p Y_{t-p}} + \varepsilon$ is an n×1 dimensional vector containing the values of all n endogenous variables in the model at time t, $\mathrm{A_1, A_2, L, A}_p$ is an n×n dimensional coefficient vector indicating the strength and direction of the interaction between variables, p is the lag order, representing the number of historical periods considered in the model, $\beta_1, \beta_2, \beta_3, \beta_4$ are regression coefficients indicating the impact of each independent variable on the dependent variable, and ε is an n×1 dimensional error vector representing the random disturbance of all variables at time t.

6. Empirical Analysis of the Development of Shanghai's Shipping Industry and the Primary Sector

6.1 *Data Collection*

Table 1: Data on Shanghai's Shipping Industry and the Primary Sector from 2002 to 2022

Years	Shanghai Primary Sector GDP (Billion Yuan)	Shanghai Waterborne Freight Volume (Billion Tons)	Shanghai Import and Export Total (Trillion USD)	Shanghai Container Throughput (Million TEUs)	CCFI Composite Index at the End of July
2002	79.68	2.3174	0.1425	0.6446	911
2003	81.02	2.6621	0.1756	11.28	1005
2004	83.45	3.0148	0.2158	14.554	1062
2005	90.26	3.4674	0.2495	18.084	1063

2006	93.81	3.7348	0.2716	21.718	1156
2007	101.84	4.1543	0.2929	26.152	1027
2008	111.8	4.3060	0.3221	28.006	1117
2009	113.82	3.7983	0.2777	25.002	880
2010	114.2	4.5407	0.3688	29.069	1005
2011	124.9	4.9389	0.4374	31.739	1040
2012	127.8	5.0302	0.4367	32.53	846
2013	129.28	4.6697	0.4413	33.62	1107
2014	124.26	4.6582	0.4666	35.29	1164
2015	109.78	4.9769	0.4676	36.54	1020
2016	109.47	4.8786	0.4777	37.13	645
2017	98.99	5.6619	0.5372	40.10	888
2018	104.37	6.6905	0.5668	42.01	833
2019	103.88	6.9980	0.5674	43.30	778
2020	103.57	9.2294	0.5804	43.50	965
2021	99.97	10.1379	0.6247	47.03	2026
2022	96.95	9.57	0.6446	47.30	3608

Shanghai's primary sector GDP (in billion yuan) grew from 79.68 billion yuan in 2002 to 96.95 billion yuan in 2022, indicating a slow growth trend. Growth was relatively faster before 2017; however, it showed a declining trend from 2020 to 2022 due to the pandemic.

Shanghai's total waterborne cargo transport volume (in billion tons) increased from 2.3174 billion tons in 2002 to 9.57 billion tons in 2022, demonstrating a clear growth trend and reflecting Shanghai's strengthened position as a major global port.

Shanghai's total import and export volume (in trillion USD) grew from 0.1425 trillion USD in 2002 to 0.6446 trillion USD in 2022, marking significant growth and indicating Shanghai's elevated status in global trade.

Shanghai's container throughput (in million TEUs) rose from 8.612 million TEUs in 2002 to 47.30 million TEUs in 2022, showing very significant growth and reflecting the rapid development of Shanghai's port and its importance in the global logistics network.

The China Container Freight Index (CCFI) at the end of July fluctuated considerably, from 911 points in 2002 to 3608 points in 2022, displaying a long-term growth trend with several years of significant fluctuations, which may reflect the instability of the global shipping market.

6.2 *Data Processing and Analysis*

This study utilizes Stata software for data processing.

6.2.1 *Descriptive Statistics*

Table 2 Descriptive Statistics of Variables

Variable	Sample Size	Mean	Standard Deviation	Minimum	Maximum
Firstindustry	21	104.91	14.647	79.680	129.28
Container	21	31.075	11.437	8.6120	47.300
Trans	21	5.2112	2.1814	2.3174	10.138
CCFI	21	1149.8	621.81	645.00	3608.0
Openness	21	0.4079	0.1515	0.1425	0.6446

6.2.2 *ADF Unit Root Test*

Given that VAR models require the variables in the system to be stationary, a unit root test is conducted on the variables involved in the model. The specific results are shown in Table 1. If a variable is not stationary, it is necessary to check for cointegration among the variables involved in the model. If cointegration exists, a vector error correction model should be used. If the variables are neither stationary nor cointegrated, differencing must be performed to achieve stationarity. Therefore, the first step is to conduct a unit root test to assess the stationarity of the time series.

Table 3 ADF Unit Root Test Results

Variable	ADF Value	5% Critical Value	10% Critical Value	Result
Firstindustry	-1.740	-3.000	-2.630	Unstable
Container	-1.983	-3.000	-2.630	Unstable
Openness	-0.840	-3.000	-2.630	Unstable
Trans	0.362	-3.000	-2.630	Unstable
CCFI	2.827	-3.000	-2.630	Unstable
ΔFirstindustry	-2.971	-3.000	-2.630	Stable
ΔContainer	-4.255	-3.000	-2.630	Stable
ΔOpenness	-4.856	-3.000	-2.630	Stable
ΔTrans	-3.392	-3.000	-2.630	Stable
ΔCCFI	0.004	-3.000	-2.630	Unstable
ΔlnCCFI	-2.806	-3.000	-2.630	Stable

The results from the table indicate that the time series for the variables Firstindustry, Container, Openness, Trans, and CCFI are significantly non-stationary. The first difference of the variable Firstindustry is stationary at the 10% significance level, the first difference of Trans is stationary at the 5% significance level, and the first differences of Container and Openness are stationary at the 1% significance level. The first difference of the logarithm of CCFI is stationary at the 10% significance level. Therefore, the VAR model is established using the time series of ΔFirstindustry, ΔContainer, ΔOpenness, ΔTrans, and ΔlnCCFI.

6.2.3 ***Stationarity Test***

To test the stability of the model, this paper utilizes the AR root model for testing. As shown in Figure 1, all inverse roots of the VAR model are less than 1, i.e., they are within the unit circle, indicating that the model is stable. This means that there is a long-term stable relationship between the variables selected in this paper, making the results derived from the VAR model valid.

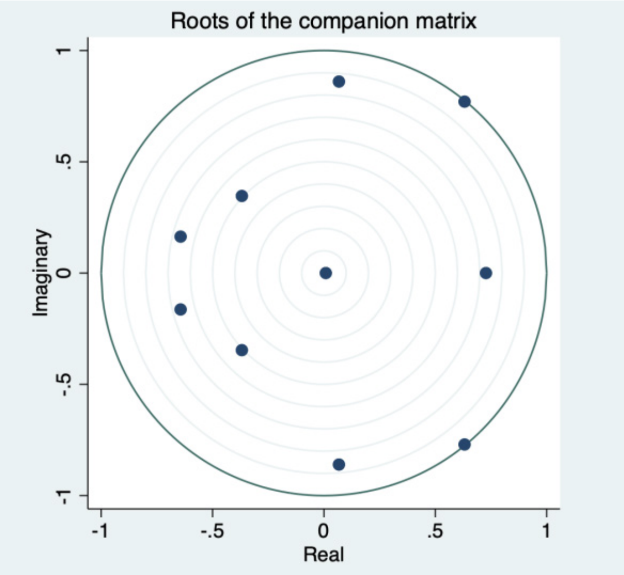

Figure 1 VAR Model Root Diagram

6.2.4 ***Cointegration***

Based on the Johansen cointegration test, regression of dFirstindustry on dContainer, dTrans, dlnCCFI, and dOpenness yields the following result:

dFirstindustry = 18.127 + 23.149dContainer + 31.252dTrans - 198.6dlnCCFI - 174.3dOpenness

(4.0704) (7.5163) (21.904) (14.62)

The residuals are stationary, indicating a long-term cointegration relationship among the variables.

6.2.5 ***Granger Causality Test***

The Granger causality test method was used to examine the causal relationships between variables.

Table 4 Granger Causality Test Results

Null Hypothesis	F-statistic	P-value	Remarks
dContainer is not a Granger cause of dFirstindustry	109.24	0.000***	Reject null hypothesis
dTrans is not a Granger cause of dFirstindustry	70.780	0.001***	Reject null hypothesis
dlnCCFI is not a Granger cause of dFirstindustry	16.668	0.000***	Reject null hypothesis
dOpenness is not a Granger cause of dFirstindustry	120.28	0.000***	Reject null hypothesis

Note: *** indicates significance at the 1% level

The Granger causality test results indicate that at the 1% significance level, Shanghai's container throughput, total import and export volume, total waterborne freight volume, and the CCFI composite index are Granger causes of the GDP of Shanghai's primary sector.

6.2.6 ***Impulse Response Results***

Using the impulse response function (IRF) based on the VAR model

Figure 2 Impulse Response Results

The impulse response results from Figure 2 show that a positive shock to container throughput leads to a peak in the primary sector's GDP in the short term, followed by a declining trend. After a one standard deviation positive shock to the total import and export volume, the primary sector's GDP does not show significant convergence. Since imports and exports are divided into goods and services, corresponding to different industries, the long-term impact on the industrial structure requires further discussion.

6.2.7 ***Variance Decomposition***

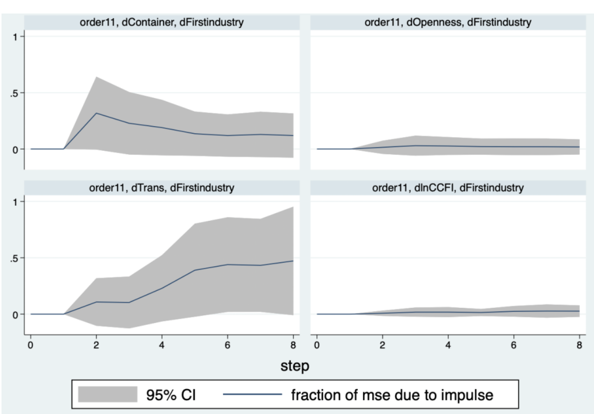

Figure 3 Variance Decomposition Results

The variance decomposition results, as shown in Figure 3, indicate that compared to Shanghai's total import and export volume and the CCFI index, Shanghai's container throughput and total waterborne freight volume account for the majority of the variations in the GDP of Shanghai's primary sector, playing a dominant role throughout. The disturbance from container throughput to the primary sector shows a decreasing trend over the long term. Meanwhile, the total volume of waterborne cargo plays an important role in the long-term increase of the GDP of Shanghai's primary sector, with its contribution gradually increasing. The variations in total import and export volume and changes in the CCFI index have relatively limited explanatory power for the variations in the GDP of Shanghai's primary sector.

7. Results Discussion

The relationship between the shipping industry and the primary sector is notably significant. ADF unit root tests, cointegration tests, and Granger causality tests reveal a long-term stable relationship between indicators of Shanghai's shipping industry—such as container throughput and the total volume of waterborne cargo transportation—and the GDP of the primary sector. The results indicate that the development of the shipping industry is a Granger cause of growth in the primary sector. This demonstrates that the shipping industry's development not only directly impacts Shanghai's economic growth but also plays a crucial role in advancing the primary sector.

Insights from impulse response analysis reveal that positive shocks to container throughput and the total volume of waterborne cargo transportation can lead to a short-term peak in the GDP of the primary sector. This suggests that rapid development in the shipping industry immediately boosts the output of the primary sector, although this effect may diminish over time.

The significance of variance decomposition is further highlighted by its results, which validate the crucial role of shipping industry indicators in explaining variations in the GDP of the primary sector. Notably, the impact of the total volume of waterborne cargo transportation on the GDP of the primary sector increases over time, while the influence of container throughput relatively weakens. This may indicate that, over time, other factors—such as technological innovation and changes in market demand—begin to exert an increasing impact on the output of the primary sector.

8. Conclusion and Recommendations

The empirical analysis utilizing the Vector Autoregression (VAR) model underscores the significant influence of Shanghai's shipping industry on the development of the primary sector. The evolution of the shipping industry not only facilitates the movement of goods and resources but also provides essential logistical support to the primary sector, particularly in agriculture and fisheries, thereby contributing to economic growth in Shanghai and beyond.

Policy Recommendations:

1. Foster Integrated Development Between Shipping and the Primary Sector

Encourage cross-sector collaboration by promoting partnerships between the agriculture, fisheries, and the shipping and logistics sectors. Establish platforms for the co-development of tailored transportation and logistics solutions for primary sector products.

Motivate logistics companies to specialize in services for primary sector commodities, such as agricultural and marine products, with a focus on cold chain logistics and swift customs clearance to enhance market competitiveness.

2. Promote Technological Innovation and Digital Transformation in the Shipping Industry

Support research and development of new technologies, offering financial incentives for innovations such as smart ports and automated loading technologies to improve efficiency and safety in shipping.

Accelerate the digitalization of the shipping industry through the adoption of blockchain, big data, and other digital technologies to enhance transparency and tracking, ensuring efficient and secure transport services for primary sector goods.

3. Optimize the Policy Environment for Shipping and the Primary Sector

Streamline administrative processes for the export of primary sector products and the operations of shipping companies, reducing operational costs and time.

Develop comprehensive policy measures that support the mutual advancement of the shipping industry and the primary sector, including financial aid, tax benefits, and simplified market access.

4. Strengthen Measures for Environmental Protection and Sustainable Development

Advocate for green shipping practices by promoting the use of low-carbon and clean energy sources, such as LNG, to transition towards a greener, low-carbon development in the shipping sector.

Support sustainable practices in agriculture and fisheries to minimize environmental impacts and enhance the green certification and market value of products.[13]

5. Enhance International Cooperation and Exchange

Broaden international cooperation through multilateral or bilateral agreements with key global shipping centers and markets for agricultural and fish products, sharing best practices to enhance the efficiency and reliability of the global supply chain.

Actively participate in the creation of international shipping and trade regulations to secure favorable global conditions and regulatory support for the nation's shipping industry and primary sector.

Implementing these recommendations can catalyze the synergistic growth of both Shanghai's shipping industry and the primary sector, elevating their global competitiveness while ensuring sustainable economic development and environmental stewardship.

Reference

[1] Fei, H., Gu, B., Wu, Z. (2012).The Necessity and Feasibility of Developing Bonded Port Area——Based on the Thought on the Construction of Shanghai International Shipping Center. Shanghai Management Science.34:71-74.

[2] Ma, X. (2021) The Relationship Between Industrial Structure And Economic Growth

——Take Shanghai as an Example. Foreign Economic Relations & Trade.35:75-79.

[3] Feng, D. (2023). An Empirical Analysis of Hainan Logistics Industry and Primary Industry Based on Multiple Regression. Logistics Sci-Tech.47:94-98.

[4] Zhang, C. (2016). Research on New Development Paths for Hebei's Primary Industry under the Background of the '13th Five-Year Plan'—An Empirical Analysis Based on Panel Data. China Market.23:54+77.

[5] Tang, C. (2012). Analysis and Prospects of the Development of the Primary Industry Economy in China—An Empirical Study Based on Panel Data. Agricultural Outlook.8:23-26.

[6] Gaydin, S., Burmakina, G. (2016). THE INFLUENCE OF SHIPPING ON THE DEVELOPMENT OF FISHING AND HUNTING IN THE YENISEI PROVINCE (1863–1917). Vestnik of Northern (Arctic) Federal University. Series "Humanitarian and Social Sciences".5:14-23.

[7] Paul, T. Oh, K. Xiao, R. (2019). Sustainability Challenges in Maritime Transport and Logistics Industry and Its Way Ahead. Sustainability.11:1331.

[8] Sun, Y. Fan, H. Peng, M. Zhuang, J. (2023). Blockchain-

Based Model for Sharing Port Logistics Transaction Data. China Water Transport.45:83-84.
[9] Zhang, H. Wu, C. Liu, Z. (2023). A Preliminary Analysis of the Shipping Industry's Focus on Dual Carbon Goals. Pearl River Water Transport.31:109-111.
[10] Zhou, X., Dai, L., Hu, H., & Zhang, M. (2024). An environmental and economic investigation of shipping network configuration considering the maritime emission trading scheme. Ocean & Coastal Management.37: 107013.
[11] Parris, D., Spinthiropoulos, K., Ragazou, K., Kanavas, V., & Tsanaktsidis, C. (2023). Measuring Eco-Efficiency of the Global Shipping Sector Based on an Energy and Environmental Approach: A Dynamic Slack-Based Measure Non-Oriented Model. Energies. 16:6997.
[12] Li, Z. Pan, W.(2015). Econometrics. Higher Education Press, PeKing.
[13] Huang, Y. Wei, M. Wang, Y. Guo, X. & Huang, M. (2023). Development Status and Trends of China's Green Shipping Logistics under the Guidance of the 'Dual Carbon' Goals. Journal of Dalian Maritime University. 49:1-16.