

RESEARCH ARTICLE

The impact of green barriers in EU countries on China's aquatic product exports

Lingsha Cai¹, Di Wu², Haiming Yu^{3*}

¹School of Management, Zhejiang University of Science and Technology, Hangzhou, Zhejiang, China

²School of Business Administration and Customs Affairs, Shanghai Customs University, Shanghai, China

³School of Economics, Zhejiang University of Science and Technology, Hangzhou, Zhejiang, China

Corresponding Author: Haiming Yu: email: yhm@zust.edu.cn

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Abstracts

Against the backdrop of increasingly stringent green trade barriers, China's aquatic product exports to the European Union have been continuously affected by growing environmental regulations. Based on this situation, this paper uses an improved trade gravity model and collects trade volume data from 2002 to 2023 for China's exports of aquatic products to 10 major EU countries. By applying a fixed effect model and combining it with the instrumental variable method, it empirically analyzes the impact of the EU's green barrier policies on China's aquatic product exports and its mechanism of action. The empirical results show that the EU's green barriers have a significant negative impact on China's aquatic product exports. Based on this result, this paper systematically summarizes the impact mechanism of the EU's green barrier policies on China's aquatic product exports through a combination of qualitative analysis and quantitative empirical research, with the aim of providing quantitative evidence and strategic suggestions for the government to formulate aquatic product export policies, promote enterprise compliance upgrades, and enhance international competitiveness.

Keywords: Green Barriers; Aquatic Product Exports; European Union; Trade Gravity Model

Introduction

Against the backdrop of increasingly stringent environmental protection policies and constant adjustments in the global trade pattern, green barriers are becoming a significant non-tariff barrier affecting the flow of international trade (Guo, 2025). From the perspective of environmental economics, green barriers embody the policy practice of internalizing environmental externalities by incorporating environmental costs such as resource consumption and pollution emissions during the product life cycle into trade conditions, they urge exporting countries to adjust their production models in order to achieve a more effective allocation of environmental resources (Li, 2025). As one of the economies with the strictest requirements for food safety and environmental protection globally, the European Union's green barrier policies have a significant impact on

global aquatic product trade (Xiao & Feng, 2025). According to data from the Food and Agriculture Organization (FAO) of the United Nations, one-third of the world's fish stocks are overfished. Meanwhile, nitrogen and phosphorus pollution in coastal waters has left some aquatic product producing areas facing the dilemma of insufficient ecological carrying capacity. Aquatic product safety and environmental sustainability have become issues of global consensus.

The European Union (EU), as one of the economies with the strictest requirements for food safety and environmental protection in the world, has its green barrier policies deeply tied to the regional demand for environmental governance. The EU's marine waters once faced ecological crises such as the reduction of fish stocks and seawater eutrophication due to problems like industrial sewage discharge and aquaculture pollution. To restore the marine ecology and ensure the environmental compliance of the food supply chain, the EU has gradually established a trade access system centered on "ecological friendliness". Its green barrier policies not only focus on product quality but also extend to the environmental impact assessment of the entire production chain, exerting a significant impact on the global aquatic products trade.

As one of the major suppliers of aquatic products to the EU, China's total export of aquatic products to EU countries reached 4.76 billion US dollars in 2022, accounting for 14.2% of China's total aquatic products export volume. However, China's aquatic products export industry still faces numerous challenges: problems such as water pollution caused by the abuse of feed in some aquaculture areas, insufficient compliance rate of waste disposal in the processing link, and incomplete carbon footprint tracking system in the supply chain, which form an obvious gap with the EU's stringent environmental standards (Zhang & Li, 2022). In recent years, with the implementation of the EU's green barrier policies, the export of Chinese aquatic products to the EU market has encountered increasing obstacles. Affected significantly by the EU's strict food safety and environmental standards, some products have been banned from entry or recalled. For China, aquatic product export enterprises still have obvious shortcomings in adapting to the EU's green barrier policies, which is particularly reflected in the gap between China's aquatic product industry standards and EU regulations, thus preventing some products from entering the EU market. In addition, the low degree of industrial chain integration means that some small and medium-sized enterprises are unable to meet the EU's high standards in terms of environmental management, production transparency, and quality control, which will further narrow the export market.

From a theoretical perspective, in light of the EU's economic trends and the economic context created by green barriers, we organize the relevant theoretical knowledge about green barriers, while also further exploring the impact mechanisms of green barriers in EU countries and their comprehensive effects on China's aquatic product exports. By simplifying and improving the trade gravity model, we can not only empirically verify the impact mechanisms of green barriers on aquatic product exports but also provide a new understanding of international trade theory.

From a practical perspective, due to the special nature of aquatic products, they have become one of the main products facing green trade barriers. The elevated market access regulations for aquatic products abroad have

imposed higher requirements on China's aquatic product exports. This paper conducts an empirical analysis of the impact of these barriers on aquatic product exports based on the trade gravity model. It provides scientific basis for government policy adjustments, international trade negotiations, and standard-setting, while also offering feasible measures for enterprises to enhance product compliance, optimize supply chain management, and improve international competitiveness.

Literature review

In recent years, with the continuous upgrading of the EU's environmental regulations and trade standards, scholars have conducted multi-dimensional research on the relationship between the EU's green barriers and aquatic product exports, resulting in abundant research outcomes. Existing research has mainly focused on three aspects: impact analysis, regional difference performance, and response strategies.

Firstly, research on the impact analysis. Some scholars believe that the implementation of the EU's green barrier policies has had a significant impact on the export volume and market structure of China's aquatic products, which is mainly reflected in the fluctuation of total export volume, the adjustment of export categories, and changes in major export markets. For example, Nie et al. (2024) pointed out that in recent years, as the EU has continuously raised standards for food safety, environmental protection, and sustainable fishing, China's aquatic product exports have faced higher market access thresholds. The EU has tightened testing standards for heavy metal content, antibiotic residues, and microbial contamination in aquatic products, forcing some enterprises to withdraw from the market as they fail to meet the requirements. The growth rate of China's aquatic product exports to the EU has slowed down significantly, with frozen fish, shrimp, and shellfish products being particularly affected. Regarding the formation mechanism, foreign researchers generally believe that green trade barriers often use environmental protection or public health as a pretext to restrict imported products by formulating strict product quality certification, production process specifications, and environmental standards. Li and Zhu (2020) showed that green barriers will restrict agricultural product exports in the short term, but may promote exports with the improvement of production technology. Moreover, due to the long adjustment cycle of agricultural production, the positive effect of green barriers on China's agricultural product exports and maritime transportation takes 3 years to emerge, while they have a positive effect on China's agricultural product exports in the current period and the third year.

Secondly, research on the regional difference performance. In terms of regional differences, domestic researchers have revealed the varying degrees of impact in different regions through typical case studies. Wang (2011) took Zhejiang Province's aquatic product exports as the research object and found that EU regulations and the MSC certification system increased enterprises' testing and certification costs by 23%-30%, and the exports of frozen aquatic products and shellfish products dropped by 12% in the first year. In contrast, due to its unique natural marine resources, some products from Hainan Province are easier to meet the EU's sustainable certification requirements, so they are relatively less affected. Overall, the upgrading of the EU's green barriers

has forced China's aquatic product export enterprises to adjust their markets, and some enterprises have shifted to markets such as Japan, South Korea, and Southeast Asia to reduce their dependence on the EU market.

Thirdly, regarding the analysis of response strategies, scholars have put forward targeted suggestions from the dual perspectives of the government and enterprises. Nie Jie et al. (2024) found that the Chinese government has taken a series of measures to improve the overall compliance of the aquatic product industry and enhance export competitiveness. They also suggested further strengthening the construction of the food safety supervision system and improving the standardization level of breeding, processing, circulation, and other links. For enterprises, they should accelerate the transformation to green and ecological breeding models, reduce reliance on chemical drugs and antibiotics, and adopt sustainable technologies such as recirculating aquaculture and deep-sea cage aquaculture. In addition, enterprises need to strengthen supply chain management and establish a full-chain traceability system from production and processing to export. Some leading enterprises have introduced block chain technology to achieve transparent supply chain management, which not only meets the EU's traceability requirements but also improves consumer trust and reduces market losses caused by non-compliance with supervision. Brandi et al. (2020) pointed out that the sustainable fisheries certification requirements introduced by developed countries in aquatic product trade are essentially hidden trade protection measures combined with environmental protection goals. Environmental agreements can help promote green exports of developing countries and reduce trade barriers, providing possibilities for developing countries to create a win-win situation. The signing of Preferential Trade Agreements (PTA) can effectively leverage the synergy between economic and environmental benefits. They also proposed that financial support can alleviate the cost pressure of enterprises by optimizing the financing structure, becoming a key mediating variable to regulate the impact of barriers. In terms of coping strategies, some studies have emphasized the dual role of policy support and technological innovation. Balogh et al. (2020) pointed out that developing countries need to establish green certification systems and early warning mechanisms to reduce export risks. The empirical study by Zhao & Gao (2025) further confirmed that financial support can not only directly promote exports but also indirectly offset the negative impact of green barriers by encouraging green innovation (such as the R&D of environmental protection technologies).

Existing studies have constructed an analytical framework for the relationship between the EU's green barriers and aquatic product exports from both domestic and foreign perspectives, forming many consensual conclusions. The academic community generally believes that green barriers have both environmental protection attributes and the nature of trade protection. They are not only non-tariff barriers set by developed countries in the name of environmental protection but also important tools for them to reshape global trade rules and strengthen control over emerging market countries. The EU's green standard system not only poses new challenges to the institutional response capabilities of developing countries but has also evolved into an integral part of its global governance strategy. Generally speaking, existing studies have clarified that green barriers are an extension of technical barriers to trade and an important symbol of global sustainable governance and the game of international rules. However, there is still room for deepening: most existing studies focus on verifying

impact effects, lacking sufficient analysis of the heterogeneous impacts on different categories of aquatic products and enterprises of different sizes; in terms of response strategies, the discussion on the "government-enterprise-international organization" coordination mechanism needs to be further in-depth. Based on this, China's aquatic product export enterprises need to face up to the dual gaps in systems and technologies, and accelerate green certification and low-carbon transformation and upgrading. At the same time, they should enhance their strategic response capabilities to green trade policies, strengthen international dialogue and rule coordination, and gradually improve their institutional discourse power in the field of green trade.

Theoretical analysis and research hypothesis

Main Forms and Characteristics of the EU's Green Barriers

As a major formulator of green trade rules, the EU's green barriers are one of the most representative and strict non-tariff barriers, and also an important institutional cost that developing countries' export enterprises have to deal with. This chapter will systematically elaborate on the main forms and characteristics of the EU's green barriers from four aspects: technical barriers to trade (TBT), environmental labels and sustainable fishing certification, packaging materials and carbon footprint restrictions, and penalty mechanisms.

Technical barriers to trade are one of the core contents of the EU's green barrier system, mainly reflected in the establishment of strict standards for pesticide residues, veterinary drug residues, heavy metal content, and microbial contamination. In recent years, the series of testing and certification measures implemented by the EU for aquatic product imports have significantly raised the export threshold for Chinese enterprises. The EU's limit standards for pesticide and veterinary drug residues in aquatic products are much higher than China's current standards. The detection limit for chloramphenicol in aquatic products is 0.3 µg/kg in the EU, while it is 0.5 µg/kg in China, showing a significant difference. In addition, the "zero-tolerance" policy for prohibited drugs such as nitrofurans and malachite green has led to frequent notifications and returns of Chinese exported aquatic products (Nie, 2024). The EU's REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) regulation stipulates that all chemical substances contained in products entering the EU market must be registered and evaluated, including packaging and processing auxiliary materials in contact with aquatic products. This places higher requirements on the production chain management of Chinese aquatic product export enterprises. The EU generally promotes the HACCP (Hazard Analysis and Critical Control Point) food safety system, requiring export aquatic product enterprises to establish a full-process hazard analysis and critical control point monitoring mechanism. Enterprises need to systematically track and record each link of breeding, transportation, and processing, significantly increasing compliance costs.

The EU's aquatic product market attaches increasing importance to environmental labels and sustainability certifications. Obtaining international certifications such as the Marine Stewardship Council (MSC) and the Aquaculture Stewardship Council (ASC) has become an important "pass" to enter large chain supermarkets and mid-to-high-end markets. MSC certification mainly targets wild-caught aquatic products, requiring enterprises

to meet international standards in terms of resource sustainability, ecological impact control, and fishery management. As of 2023, only 16.8% of China's aquatic product enterprises have obtained MSC certification, significantly lower than Vietnam and Norway. The green certification requirements are essentially "exclusive", forming a de facto market barrier (Zhao & Yuan, 2025). In contrast, Vietnam has promoted ASC certification and sustainable aquaculture systems through government and enterprise collaboration, enhancing the competitive advantage of its export products in the EU market (Kang et al, 2020).

The EU also has strict requirements for the packaging materials, transportation methods, and carbon emission data of imported products. To address climate change and promote low-carbon economic development, the EU has gradually implemented a carbon footprint accounting system and officially launched the Carbon Border Adjustment Mechanism (CBAM) in 2023 (Li & Zhang, 2025). Although aquatic products have not yet been directly included in the CBAM regulatory list, the carbon emissions from their packaging, cold chain transportation, and storage have already attracted attention. Regarding packaging, the EU has banned the use of non-biodegradable materials such as PVC and requires the labeling of material sources, recyclability, and ecological impact. Aquatic products that do not meet the environmental packaging requirements often encounter entry obstacles due to packaging issues. In terms of transportation methods, the energy efficiency of the cold chain system has become a key point in assessing carbon footprints (Zhao et al, 2024). The EU encourages the use of low-carbon transportation tools and requires enterprises to submit relevant certification reports. At the same time, the EU market generally adopts a carbon label system, and some large-scale purchasers prioritize products with lower carbon footprints in their procurement decisions. China's export aquatic products lack the ability to calculate carbon footprints, putting them at a disadvantage in competition with Nordic countries.

To ensure the implementation of green trade rules, the EU has a complete set of punishment mechanisms, taking dynamic notifications, entry restrictions, forced recalls, and suspension of qualifications as various punitive measures against countries and enterprises that violate green standards. The most common method is to issue notifications through the Rapid Alert System for Food and Feed (RASFF). RASFF notifications have the function of cross-border information sharing, creating a credit blockade effect on enterprises. In severe cases, it may even affect their export qualifications in other countries. Additionally, the EU has a "Special Intensified Monitoring Mechanism," which implements 100% batch inspections for high-risk countries or product types. For instance, some aquatic product enterprises in key export provinces such as Fujian and Shandong have been included in this mechanism due to consecutive notifications.

Based on the above four main aspects of the EU's green barriers, it can be concluded that the current EU green barriers exhibit a comprehensive characteristic of "hardening standards, institutionalizing certification, ecologicalizing assessment, and dynamicizing supervision," serving as a systematic, continuous, and multi-dimensional export restriction tool. It not only tests the product quality control capabilities of exporting countries but also their institutional responses and green governance levels.

The dual impact pathways of EU green barriers

The EU's green barriers not only directly compress the export volume through technical thresholds and market access restrictions but also indirectly influence China's aquatic product exports by increasing compliance costs and forcing industrial structure upgrades. This chapter will analyze the specific impacts from both the direct and indirect effects of the EU's green barriers.

Direct Impact: Technical Thresholds and Market Access Restrictions Affect Export Volume. The implementation of the EU's green barrier policies has significantly affected the export volume and market structure of China's aquatic products, mainly reflected in changes in total export volume, adjustments in export categories, and changes in major export markets. In recent years, due to the EU's continuous improvement of standards for food safety, environmental protection, and sustainable fishing, China's aquatic products face higher market access thresholds. The number of cases where Chinese export enterprises have been notified has increased, with the majority being due to excessive antibiotic residues, followed by heavy metal pollution and microbial contamination. Some notifications are also due to the lack of traceability, reflecting the low level of informationization in production management and supply chain transparency in China. Moreover, green labels are also a significant feature of the EU's procurement market. For example, MSC and ASC certifications are the basic thresholds for supermarket procurement, covering 85% of their high-end market purchases. As of 2023, only 16.8% of Chinese export enterprises have obtained certifications, while the proportions for Norway and Vietnam are 47.3% and 29.5%, respectively. Un-certified enterprises' products are forced to shift to low-end distribution markets, with their price negotiation capabilities declining by 18% to 22%. In terms of packaging, the EU requires that product packaging use biodegradable materials and clearly label environmental information. The energy efficiency of transportation and storage is also included in the carbon footprint assessment index system, and the carbon emission audits for cold chain aquatic products are becoming increasingly strict year by year (Wang et al, 2023). These have further increased the difficulty for Chinese enterprises to enter the market, largely resulting in a reduction in export volume and affecting export value (Cheng et al, 2024).

Indirect impacts: cost amplification, industry development forced to upgrade and market transfer. Green barriers, based on technical standards and compliance requirements, set a series of complex entry thresholds, such as limits on pesticide and veterinary drug residues, heavy metal control, environmental sustainability certification, carbon emission accounting, etc. If enterprises fail to meet these requirements, they will have to apply for certification, carry out technological transformation, disclose data, and build information traceability systems, all of which will increase their operating costs. Especially for small-scale fishing households, this will increase their production pressure and lead to their withdrawal from the market. At the same time, for processing enterprises, the profit margins in the processing stage are greatly compressed, and the profit rate drops significantly. The increase in compliance costs weakens the price competitiveness of the vast majority of Chinese aquatic product enterprises in the international market. Particularly for small and medium-sized enterprises, expenditures such as certification fees, packaging replacement, and cold chain carbon audits

severely squeeze their profit margins, and some enterprises are even forced to withdraw from the EU market due to insufficient technical and financial capabilities. Eventually, market share shifts in competition (Fu et al, 2024). In the EU procurement chain, green labels and certifications are often regarded as default thresholds. Even if un-certified products are cheaper, they are difficult to enter the high-end procurement system, leading to a reduction in export scale and loss of market share, and forcing the export structure to shift towards low-value-added or marginal markets. Enterprises that are forced to shift their markets to Southeast Asia face price drops and lower prices for similar products, encountering the dilemma of market diversification (Qin et al, 2024). However, at the same time, green barriers, by increasing compliance costs and entry thresholds, accelerate the elimination of low-end production capacity of small and medium-sized enterprises, to a certain extent promoting the transformation of the industry towards deep processing, high technology, and high value-added. Under the impact, enterprises increase their R&D investment, the proportion of high-value-added categories such as frozen fish in exports increases, and the industrial chain gradually extends to ecological aquaculture, green packaging, and low-carbon transportation (Xia, 2022).

The research hypothesis

From the above, it can be seen that the impact of the EU's green barriers on China's aquatic product exports is multi-dimensional and gradual. To more clearly examine the specific impact of green barriers on aquatic product exports, based on theoretical foundations and actual EU policies, this paper proposes the following research hypothesis: The stricter the EU's green trade barriers, the lower the domestic aquatic product export trade volume. The improvement of strict testing standards and certification standards will increase the risk of non-compliance of export products, raise compliance testing costs, and some small and medium-sized enterprises will lose export opportunities due to their inability to bear frequent testing and standard upgrades, leading to a decline in overall export volume.

Methodology

To comprehensively analyze and assess the impact of the EU's green barrier policies on China's aquatic product exports, this chapter simplifies and improves the global trade gravity model to evaluate the influence of green trade barrier policies, the GDP of the importing and exporting countries, exchange rate fluctuations, transportation distance, and other factors on the trade volume of domestic aquatic product exports to the EU.

Simplification and Improvement of the Trade Gravity Model

The gravity model is a powerful tool for predicting trade volumes between countries. Its basic model formula is as follows:

$$T_{ij} = A \frac{Y_i \times Y_j}{D_{ij}} \quad \text{Equation (1)}$$

In the model, Y_i and Y_j respectively represent the gross domestic product (GDP) of the importing and exporting countries. The model holds that larger economies are more involved in global trade. D_{ij} represents the straight-line distance of bilateral trade, and the model assumes that distance to some extent represents trade costs; the greater the distance, the smaller the trade volume.

Based on the trade gravity model, this study logarithmically transforms the model's formula, converting it into a simple multiple linear regression model:

$$\ln T_{ij} = \alpha + \beta_1 \ln Y_i + \beta_2 \ln Y_j - \beta_3 \ln D_{ij} + \epsilon_{ij} \quad \text{Equation (2)}$$

In addition, considering the nature of China's exports of aquatic products to the EU, this study adds the dummy variables and exchange rate fluctuation variables of EU green trade barriers to the above model, and constructs an improved trade gravity model:

$$\ln Trade_t = \alpha + \beta_1 \ln (Green Barrier_t) + \beta_2 \ln (GDP_{it}) + \beta_3 \beta_2 \ln (GDP_{jt}) + \beta_4 \ln (DT_{ij}) + \beta_5 \ln (ExchangeRate_t) + \epsilon_{ij} \quad \text{Equation (3)}$$

The symbols and calculation methods of the model variables are shown in Table 1 below:

Table 1. Explanation of Explanatory Variables

Variable Type	Variable Symbol Variable	Description	Calculation Method
Dependent variable	Trade	Imports of aquatic products	The natural logarithm of the trade value of aquatic products imported by EU country i in year t (USD) is used.
	GDP	gross domestic product	The natural logarithm of the GDP (USD) of China and EU countries j in year t is used
Control variables	DT	Shipping distance	The natural logarithm of the geographical distance (km) between the two countries, measured in terms of the distance between the capitals, reflects the cost of transportation
	ExchangeRate	exchange rate	The natural logarithm of the exchange rate of USD/RMB in year t is used to

reflect the impact of exchange rate fluctuations on trade.

Argument	GreenBarrier	Green Barrier Indicator	The EU's policies and regulations on green barriers to imported aquatic products, the strictness of inspection standards, and the number of inspection restrictions are used to set dummy variables
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Data source

Taking the trade export value as the interpretation object of the model, this paper selects the relevant data of ten main destinations of China's aquatic products exported to the EU from 2002 to 2023, namely Spain, the Netherlands, the United Kingdom, Germany, Sweden, Poland, Denmark, France, Portugal and Belgium, to form a panel data. Among them, although the UK has left the European Union, the relevant policies, regulations and technical standards of its green barriers have not been independently transitioned, and it is estimated that they are still covered by the analysis.

The data is collected from official and industry-recognized databases, and strives to be authentic and rigorous. Among them, China's annual imports of aquatic products to EU countries (Tradejt) are downloaded from the United Nations Comtrade Database. Gross domestic product (GDP) of countries is obtained by searching from the World Bank Open Data database. The Exchange Rate data for USD/CNY is retrieved from a publicly available database search by the International Monetary Fund (IMF). The EU's Green Barrier Index (GreenBarrier) comprehensively considers the several forms of EU green barriers mentioned above, such as the strictness of technical trade barriers, environmental labeling and sustainable fishing certification requirements for imported aquatic products, packaging materials and carbon footprint and other constraints, to construct a virtual index score of EU green trade, with a score range of 0-1. Considering that the data analyzed in this paper covers the period from 2002 to 2023, Table2shows the changes in the EU's regulations on the import of aquatic products from China during this period.

Table 2. Changes in EU regulations

Effective Year	Name of the regulation	Main content:	Testing criteria
2001	Commission Regulation (EC) No 466/2001	The maximum residue limits of cadmium, mercury and lead in fish were changed from 1000 mg/kg to 50 mg/kg, 500 mg/kg and 200 mg/kg respectively	Heavy metal residues
2002	Commission Directive 2002/69/EC	The ban on all imports of products of animal origin from China was later revised to resume imports but to introduce higher and stricter inspection standards	9 new detection indicators for microorganisms, 5 heavy metals, and 9 pesticide and veterinary drug residues were added
2002	2002/994/EC	It is forbidden to import from China three types of sea-caught aquatic products, including shrimp and eel	-
2002	Regulation (EC) No 178/2002	Aquatic products are required to have a traceable label, otherwise they are not allowed to enter the EU market	-
2005	2005/34/EC	New regulations have been made on the issue of drug residues in animal-derived products, such as chloramphenicol content less than 0.3mg/kg and nitrofurans metabolites less than 11mg/kg	Residues of prohibited substances must be below the minimum enforcement limits

Effective Year	Name of the regulation	Main content:	Testing criteria
2006	(EC)852/2004、001/466/EC853/2004、001/466/EC854/2004	Strengthen food safety inspections, improve market access standards, increase the accountability of operators, and pay attention to the safety of the production process	-
2017	Regulation (EU) 2017/625	There are three types of inspections for imported products, namely document inspections, identity inspections, and physical inspections	-
2023	(EU)2023/710	Revision of the MRLs for 5 pesticides, including bromodifen, in certain products	Pesticide residues and maximum residue levels (mg/kg)
2023	(EU)2023/174	Revision of the temporary addition of official controls and emergency measures to regulate the entry of certain goods from certain third countries into the EU	Accompanied by details of the laboratory analytical method and all results, at least the hazard items identified in Annex II of Implementing Regulation (EU) 2019/1793 are covered
2023	(EU)2023/915	A new version of the Contaminant Limits in Food Regulation was introduced, replacing (EC) No 1881/2006	Regulate the limits of contaminants in food

Note: The data comes from the official website of the European Union

Results and discussions

Sample descriptive statistics

In this paper, panel data from 2002 to 2023 are established, with 220 observations. In order to get a preliminary understanding of the characteristics of each variable, the sample size, mean, standard deviation, maximum, minimum, and median of each variable are described in this section, and the results are shown in Table 3.

Table 3. Descriptive statistical analysis of the sample

Variables	Obs	Mean	Std.Dev.	Min	Max
$\ln Trade_t$	220	18.236	1.222	12.57	20.25
$\ln GreenBarrier_t$	220	0.646	0.064	0.61	0.81
$\ln GDP_i$	220	29.771	0.51	28.82	30.47
$\ln GDP_j$	220	25.521	2.208	21.13	28.94
$\ln DT_{ij}$	220	8.971	0.116	8.81	9.18
$\ln ExchangeRate_t$	220	1.944	0.099	1.8	2.11

Correlation analysis

In the previous part, we have conducted a descriptive statistical analysis of the sample data, and found that the data used in this paper have a certain degree of rigor and reasonableness, and then the correlation degree between the variables is preliminarily judged through correlation analysis. In this section, the Pearson coefficient is used to test the correlation of each variable, and the test results are shown in Table 4.

Table 4. Correlation analysis between variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) $\ln Trade_t$	1.000					
(2) $\ln GreenBarrier_t$	-0.305* (0.000)	1.000				
(3) $\ln GDP_i$	0.442* (0.000)	-0.104 (0.125)	1.000			
(4) $\ln GDP_j$	0.358* (0.000)	0.027 (0.687)	0.714* (0.000)	1.000		
(5) $\ln DT_{ij}$	0.204* (0.002)	0.000 (1.000)	0.000 (1.000)	-0.104 (0.123)	1.000	
(6) $\ln ExchangeRate_t$	-0.462* (0.000)	0.392* (0.000)	-0.745* (0.000)	-0.405* (0.000)	0.000 (1.000)	1.000

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

It can be seen that the correlation between the export value of the explanatory variable and the explanatory variable trade barrier index selected in this paper is negative, and the correlation coefficient is -0.305^{***} ($p=0.000$), indicating that there is a certain degree of negative correlation between the two, indicating that the trade barrier index may have an inhibitory effect on aquatic exports. In addition, the correlation coefficient between the explanatory variable aquatic product export value and China's GDP was 0.442^{***} ($p=0.000$), and the correlation coefficient was 0.358^{***} ($p=0.000$) with the GDP of EU countries. However, it should be noted that correlation analysis can only preliminarily determine the relationship between variables, and cannot substantially prove the causal relationship between variables, so we need to further analyze and discuss the sample data to obtain more accurate conclusions.

Multicollinearity

The multicollinearity test was conducted on the model. As shown in Table 5, the average VIF value of the model is 2.409, which is far lower than the empirical threshold of 5, indicating that the model has a low risk of multicollinearity. A detailed analysis of each variable shows that the VIF values of $\ln GDP_i$ and $\ln ExchangeRate_t$ are 4.39 and 3.071, respectively. Considering the characteristics of the data, this collinearity may be caused by the inherent correlation between economic variables, and there may be a mutually influential relationship between GDP and exchange rate in economic theory. The VIF value of $\ln GDP_j$ is 2.256, which is relatively low, while the VIF values of $\ln GreenBarrier_{ij}$ and $\ln DT_{ij}$ are 1.306 and 1.025, respectively, suggesting a low risk of collinearity.

Table 5. Results of Multicollinearity Test

	VIF	1/VIF
$\ln GDP_i$	4.39	0.228
$\ln ExchangeRate_t$	3.071	0.326
$\ln GDP_j$	2.256	0.443
$\ln GreenBarrier_t$	1.306	0.766
$\ln DT_{ij}$	1.025	0.976
Mean VIF	2.409	

Stationarity Test

To ensure the validity of the model and considering the unbalanced panel data, we conducted a stationarity test on the model variables (excluding dummy variables) using the IPS (Im-Pesaran-Shin) method. The results are presented in Table 6, indicating that the model variables are generally stationary. The test statistics and their corresponding p-values are key indicators for determining stationarity. For the variables $\ln Trade_t$, $\ln GDP_i$, and $\ln ExchangeRate_{ij}$, their p-values are all less than 0.05, providing sufficient evidence to reject the null hypothesis

of a unit root. Therefore, these variables are considered stationary. The relatively high p-value of $\ln GDP_j$ is attributed to significant GDP disparities across different cross-sections (countries).

Table 6. Results of Stationarity Test

Variable	IPS	
	Statistic	p-value
$\ln Trade_t$	-6.2245	0.0000
$\ln GDP_i$	-8.7646	0.0000
$\ln GDP_j$	1.8080	0.9647
$\ln DT_{ij}$	/	/
$\ln ExchangeRate_{ij}$	-1.7866	0.0370

Benchmark Regression Analysis

To determine the appropriate empirical model for this study, we conducted the F-test and Hausman test. The results are presented in Table 7 and 8. Both the F-test and Hausman test reject the null hypothesis at the 1% significance level, indicating that the fixed effects model is the optimal choice.

Table 7. Results of F-Test

Model	F(10,194)	Prob>F	Conclusion
F-Test	79.40	0.0000	Reject the pooled OLS model

Table 8. Results of Hausman Test

Model	chi2(4)	Prob>chi2	Conclusion
Hausman Test	2.08	0.0000	Reject the random effects model

After conducting the above model specification tests, we employed the fixed effects model to perform a benchmark regression analysis on the sample data. The results are presented in Table 9.

Table 9. Results of Fixed Effects Regression Analysis

	(1)	(2)
	lnTrade _{ij}	lnTrade _{ij}
lnGDP _i	0.892*** (5.563)	1.087*** (7.498)
lnGDP _j	-0.102*** (-2.895)	-0.096*** (-3.070)
lnDT _{ij}	0.000 (.)	0.000 (.)
lnExchangeRate _{ij}	-3.112*** (-5.598)	-1.283** (-2.326)
lnGreenBarrier _{ij}		-4.037*** (-7.464)
_cons	0.337 (0.067)	-6.549 (-1.446)
N	220	220
R ²	0.590	0.678
F	98.923	107.823
Note: ***p<0.01, **p<0.05, *p<0.1		

The results show that after adding the control variables, the impact of the explanatory variable lnGreenBarrier_{ij} on the explanatory variable lnTrade_{ij} is negative and significant at the 1% level. The impact coefficient is -4.037, which indicates that the export trade of aquatic products will decrease by 4.037 units for every unit of green barrier improvement under other conditions, which verifies the hypothesis of this paper.

Among the control variables, the impact of lnGDP_i on aquatic product export trade is positive and significant at the level of 5%, indicating that the increase of domestic GDP will promote the improvement of aquatic product export trade to a certain extent under other conditions. The possible reason is that a higher GDP usually means that a country or region has stronger economic strength and greater market demand, which will promote the development of aquatic product export trade. The impact of lnGDP_j on aquatic product export trade is negative and significant at the 5% level, which indicates that the increase of foreign GDP may inhibit aquatic product export trade, which may be related to the protective policies of importing countries for their own industries. The impact of lnDT_{ij} on aquatic product export trade is not significant, which may indicate that the impact of distance factor on aquatic product export trade is small or there are other complex influencing mechanisms. The impact of lnExchangeRate_{ij} is negative and significant at the 1% level, suggesting that an increase in the exchange rate may inhibit the export trade of aquatic products, which may be due to the increase in the exchange rate increasing the cost of exports, thereby reducing the competitiveness of exports.

In conclusion, through the results of benchmark regression analysis, we can see that the development of green barriers has a significant inhibitory effect on aquatic product export trade under other conditions, which verifies

the hypothesis of this paper, and at the same time, the increase of domestic GDP will promote the development of aquatic product export trade, while the increase of foreign GDP and the increase of exchange rate may inhibit aquatic product export trade.

Endogeneity test analysis

To address the potential endogeneity issue in the model, this paper uses the one-period lagged green trade barrier index ($\text{laglnGreenBarrier}_t$) as an instrumental variable and performs two-stage least squares (2SLS) estimation on the sample data. Results are shown in Table 10.

Table 10. Results of Endogeneity Regression Test

	(1) GreenBarrier _t	(2) Trade _t
laglnGreenBarrier _t	0.535*** (0.066)	
lnGDP _i	0.092*** (0.014)	1.136*** (0.193)
lnGDP _j	-0.006** (0.003)	-0.089*** (0.032)
lnDT _{ij}	0.000 (.)	0.000 (.)
lnExchangeRate _{ij}	0.233*** (0.053)	-0.317 (0.755)
lnGreenBarrier _t		-6.112*** (1.306)
_cons	-2.727*** (0.428)	-8.758 (5.928)
N	209.000	209.000
r ²	0.463	
F	41.882	
FixedEffects	Yes	Yes

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In the first-stage regression, we primarily test the impact of the instrumental variable ($\text{laglnGreenBarrier}_t$) on the endogenous variable (lnGreenBarrier_t). The results show that $\text{laglnGreenBarrier}_t$ is statistically significant (coefficient = 0.535, $p < 0.01$), indicating that the instrumental variable has a good explanatory power for the endogenous variable. Specifically, the F-statistic of the first-stage regression is 41.882, which is far greater than the usual critical value of 10, suggesting that the instrumental variable is a strong one. This passes the weak

instrumental variable test, proving that the selected instrumental variable in this paper is reasonable.

In the second-stage regression, $\text{lagLnGreenBarrier}_t$ is used as an instrumental variable to estimate the impact of LnGreenBarrier_t on LnTrade_t . It can be seen that although LnGreenBarrier_t has a statistically significant effect on Trade_t (coefficient = -6.112, $p < 0.01$), the regression results of the second stage show that the model's explanatory power (R^2) is 0.463, indicating a good goodness-of-fit to the data. This suggests that at least one instrumental variable is effective, and through the two-stage least squares estimation method, we have effectively addressed the endogeneity problem of the model.

Robustness Test

To verify the robustness of the model selected in this paper, two methods were used to conduct robustness tests on the model. In the first method, based on the original sample data and model, the export trade volume measuring China's ability to export aquatic products to the EU was replaced with trade weight to verify the robustness of the hypothesis in this paper. In the second method, on the basis of the original fixed effects model, the sample data were winsorized at the top and bottom 1% to reduce the impact of outliers in the sample on the estimation results and ensure the robustness and reliability of this study. As shown in the table, in both Model 1 with the explained variable replaced and Model 2 with winsorization, the impact of green barriers ($\text{LnGreenBarrier}_{ij}$) on the explained variable remained negative and significant at the 1% level, which is consistent with the benchmark regression results. Although the impact coefficients varied, they were within the normal fluctuation range. Specifically, the coefficient of green barriers was -3.419 in Model 1 and -3.526 in Model 2, both significant at the 1% level.

In addition, the impact of domestic GDP (LnGDP_i) on trade weight (LnWeight_{ij}) was positive and significant at the 5% level, with a coefficient of 0.791, indicating that an increase in domestic GDP will promote the development of aquatic product export trade to a certain extent. The impact of foreign GDP (LnGDP_j) was negative and significant at the 5% level, with a coefficient of -0.088, suggesting that an increase in foreign GDP may inhibit aquatic product export trade. The impact of distance (LnDT_{ij}) was not significant in Model 1 but became positive and insignificant in Model 2, with a coefficient of 2.046. The impact of exchange rate ($\text{LnExchangeRate}_{ij}$) was negative and significant at the 5% level, with coefficients of -2.062 in Model 1 and -1.485 in Model 2.

Thus, it can be concluded that under different model specifications and data conditions, the development of green barriers has a significant inhibitory effect on aquatic product export trade, while an increase in domestic GDP promotes the development of aquatic product export trade. The conclusions of this paper have passed the robustness test and are highly credible.

Table 11. Results of Robustness Test

	(1) Variable Replacement lnWeight _{ij}	(2) Winsorization Trade _{ij}
lnGDP _i	0.791*** (5.317)	0.967*** (6.957)
lnGDP _j	-0.088*** (-2.736)	-0.082*** (-2.792)
lnDT _{ij}	1.015 (0.738)	2.046 (0.976)
lnExchangeRate _{ij}	-2.062*** (-5.947)	-1.485*** (-2.808)
lnGreenBarrier _{ij}	-3.419*** (-4.358)	-3.526*** (-6.698)
_cons	-15.081 (-0.606)	-21.556 (-1.120)
N	220	216
R ²	0.2105	0.1708
F	105.02	97.96
Note: ***p<0.01, **p<0.05, *p<0.1		

This section discusses the analytical effectiveness and limitations of the fixed effects model constructed in this paper. Overall, the model can effectively explain the impact of green barriers on aquatic product export trade, and the selected control variables are reasonable and scientific. However, the model has some deficiencies in terms of external validity, variable selection, and calculation methods.

Due to limitations in data availability, the national data collected in the study only includes the top 10 EU exporting countries and is limited to normally operating enterprises, excluding unlisted companies. This indicates that the model's analysis results may only apply to similar enterprises in the same region and cannot be directly generalized to other regions or all enterprises. Additionally, although the model considers some control variables, its structure is relatively simple and does not include other variables that may significantly affect trade, such as industry competition indices and green innovation investment, which limits the model's explanatory power to a certain extent. In regions with a highly developed aquatic product industry, enterprises typically invest more in environmental, social, and governance (ESG) aspects and may respond more deeply and effectively to green barriers.

The model also has limitations in the definition methods of variables. For example, the "GreenBarrier" index

may not fully reflect the specific impact of green barriers in actual trade. These factors may affect the model's accuracy and applicability, which need to be further improved and refined in future research. By adding more variables and refining the model structure, the explanatory and predictive capabilities of the model can be enhanced, making it more suitable for enterprises in different regions and of different scales.

Conclusion

Based on the institutional characteristics of EU green barriers and the actual situation of China's aquatic product exports, this study analyzes the main forms of green barriers, China's export status quo, enterprise adaptability, and empirical results, leading to the following conclusions: First, the EU green barriers have formed a systematic institutional system centered on technical trade barriers, environmental label certification, packaging and carbon footprint control, and violation punishment mechanisms, exerting a systematic impact on China's aquatic product exports. Its technical standards are strict and detailed, with a wide coverage that not only examines product safety indicators but also extends to the ecological impact of the entire process from production, transportation, to packaging (Wu et al, 2023). Second, in terms of export scale and structure, China's aquatic product exports to the EU have generally shown a steady upward trend, but the category concentration is high, mainly focusing on frozen fish, shrimp, and shellfish. Frequent green barrier incidents mainly concentrate on excessive drug residues, microbial contamination, and insufficient traceability. Some enterprises have been frequently notified by RASFF, indicating rising export risks and significant pressure on production costs. Third, empirical analysis shows that EU green barriers have a significant negative impact on China's aquatic product export trade, while the growth of domestic GDP can promote aquatic product exports to a certain extent.

In summary, as a new hotspot in international trade competition, green barriers have exerted multi-faceted pressures on the compliance system, export model, and sustainable development capacity of China's aquatic product industry. In the future, it is necessary to strengthen the linkage between the aquatic product industry and policies, promote the implementation of the "green export strategy," and lay a solid foundation for a higher-quality, lower-risk, and more sustainable export development path for China's aquatic product industry.

The primary response to green barriers is to ensure the quality and safety of aquatic products through source management. It is recommended that national and local authorities implement stricter quality and safety supervision systems across the entire industry chain. On the one hand, accelerate the formulation of key indicator standards aligned with international practices, particularly the EU system; on the other hand, strengthen source management in the aquaculture sector, standardize the use of antibiotics and prohibited drugs, and implement sampling traceability and product recall systems (Zhu, 2024). Additionally, guide enterprises to establish a Hazard Analysis and Critical Control Point (HACCP) system covering the entire process from seedling, breeding, processing to export, and build verifiable and quantifiable quality safety files to ensure full-process quality control from "farm to table."

Accelerate the establishment of a green standard support system centered on international mainstream

certifications such as MSC and ASC to adapt to the increasingly strict EU requirements for aquatic product green certification. The government can set up special funds to subsidize certification training and audit fees, reducing the certification threshold for small and medium-sized enterprises. Meanwhile, concentrate certification resources on key export regions and leading enterprises, cultivating a group of "green export demonstration enterprises" and "certification-driven industrial clusters." Finally, establish a green certification database and information sharing platform to provide enterprises with services such as certification updates, standard changes, and successful cases, improving certification efficiency and transparency for large-scale, systematic, and normalized operations (Tang, 2023).

Aiming at the "information lag" problem, establish a national-level "Green Trade Regulations Monitoring Platform" to track EU TBT/SPS notifications, RASFF warnings, and CBAM carbon border adjustment policies in real time, and promptly release early warning information to enterprises. Meanwhile, rely on universities and research institutions to form a "green trade think tank," strengthening the interpretation of EU legal clauses, trend prediction, and response strategy research to provide professional decision support for policy departments and enterprises (Shang & Xia, 2024). Encourage industry associations to play a bridging role in notification analysis, compliance guidance, and dispute coordination, enhancing the overall response capacity of the industry.

Enterprises must enhance their green production and management capabilities to better address green barriers. Encourage enterprises to increase investment in environmental technology upgrades, promoting the transformation of traditional aquaculture to an ecological, intelligent, and modern system. Guide enterprises to apply green technologies such as recirculating water aquaculture, tailwater treatment, and energy-saving cold chain to reduce environmental impacts (Chen et al, 2024). Additionally, establish a "green financial incentive mechanism" to direct funds to green aquaculture enterprises through green credit and green guarantees. For fishery resources meeting sustainable fishing standards, prioritize MSC, ASC, and other certification work to expand the supply of sustainable products (Sheng, 2023). At the government level, formulate green product priority export lists and set up green brand reward policies to enhance the recognition and price negotiation capability of sustainable aquatic products in the EU market.

Although the EU market remains an important destination for China's aquatic product exports, facing the trend of stricter green barriers, it is necessary to accelerate the diversification strategy of export markets. Market diversification not only provides more trade opportunities for Chinese enterprises but also helps avoid export risks to a certain extent. By leveraging the "Belt and Road" cooperation mechanism, actively expand emerging markets in Southeast Asia, the Middle East, Africa, and Central Asia, and promote bilateral or multilateral agreements with partner countries on mutual recognition of aquatic trade standards and green certification interoperability to reduce institutional barriers in non-EU markets (Nguyen, 2023). Accelerate the layout of overseas warehouses, cold chain logistics, and overseas marketing networks to enhance service capabilities and response efficiency in emerging markets. For new products and markets with export potential, the state can establish special support projects to provide comprehensive services such as market research, trade

matchmaking, and brand promotion, alleviating export enterprises' high dependence on the EU market and enhancing risk resistance.

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