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RECEIVED 07 November 2025
REVISED 22 January 2026
ACCEPTED 29 January 2026
PUBLISHED 18 February 2026

CITATION
Cai Y, Chen W and Zeng X (2026) The
impact of the depth of environmental
provisions in regional trade agreements
on China's fisheries and aquaculture
trade.
Front. Sustain. Food Syst. 10:1741505.
doi: 10.3389/fsufs.2026.1741505

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The impact of the depth of environmental provisions in regional trade agreements on China's fisheries and aquaculture trade

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Based on a panel data covering China and 47 major partner countries from 2000 to 2019, this study employs an extended gravity model to systematically examine the impact of environmental provisions depth in regional trade agreements on China's fisheries and aquaculture products trade. The results show that deeper environmental provisions significantly reduce China's aquatic product imports but have no significant effect on exports. The robustness of these findings is supported by endogeneity corrections and multiple robustness checks. Heterogeneity analysis reveals clear structural differences. Trade restrictive provisions significantly reduce imports, whereas trade facilitative provisions exert no notable effect; the import-reducing effect is particularly pronounced in long-distance trade and high-income country markets, but insignificant in short-distance and non-high-income country samples, highlighting the critical moderating roles of geographic distance and development level in determining the effectiveness of institutional rules. This study is the first to focus specifically on China's fisheries and aquaculture sector, providing empirical evidence on the economic effects of green trade rules.

KEYWORDS

environmental provisions depth, fisheries and aquaculture, gravity model, Poisson pseudo-maximum likelihood, regional trade agreements

1 Introduction

In recent years, regional trade agreements (RTAs) have evolved from traditional instruments for tariff reduction into deep integration arrangements encompassing rules across multiple domains. An increasing number of agreements now incorporate non-economic objectives such as environmental protection, labor standards, and civil rights and human rights (Hofmann et al., 2019). Particularly in the environmental domain, approximately 60% of RTAs signed globally after 2010 contain environmental provisions (Yue and Lin, 2024), which not only address cooperation on environmental protection but also emphasize promoting sustainable development through trade mechanisms. Since 2002, China has actively engaged in regional economic cooperation, gradually introducing environmental content into its RTAs with countries such as Chile, New Zealand, Switzerland, and South Korea. China's RTAs have gradually incorporated environmental provisions, evolving from the initial absence of such clauses to the inclusion of increasingly specific and legally binding commitments (Zhu and Sun, 2025). Based on statistics from the Trade and Environment Database (TREND), China-Hong Kong FTA in

2003 contained only four environment-related clauses, whereas the China–Republic of Korea FTA signed in 2015 includes 104 environmental provisions, reflecting the rising prominence of environmental issues in China’s external economic and trade negotiations.

This shift carries particular significance for sectors that are both economically vital and ecologically sensitive—one such sector being fisheries and aquaculture. China is the world’s largest producer and exporter of fish and aquaculture products (hereinafter referred to as aquatic products), with the fisheries and aquaculture sector playing a significant role in agricultural economy and foreign trade. Despite facing resource constraints and environmental pressures, China’s aquatic product trade has maintained a large scale in recent years, with major export markets including Southeast Asia, the European Union, Japan, and the United States. According to the Food and Agriculture Organization (FAO), China’s aquatic product imports reached USD 17.209 billion in 2021, accounting for 10% of the global total, while exports amounted to USD 21.265 billion, representing 12.1% of global exports. In the same year, aquaculture and fisheries production accounted for 54.6 and 14.2% of global output, respectively (FAO, 2024).

However, this industry is highly dependent on natural resources and ecologically sensitive, with its aquaculture, fishing, and processing stages often associated with water resource consumption, marine pollution, and ecosystem degradation, making it particularly vulnerable to international environmental regulations. As environmental provisions in RTAs become increasingly stringent—especially those concerning sustainable fisheries management, combating illegal, unreported, and unregulated (IUU) fishing, and restrictions on chemical use—new compliance requirements and technical barriers are emerging for China’s aquatic product trade (Liu et al., 2022). Against this backdrop, investigating how environmental provisions in RTAs affect the trade flows of China’s aquatic products not only helps evaluate the actual effectiveness of current free trade policies but also provides practical evidence for promoting green transformation in fisheries and aquaculture.

Existing studies indicate that environmental rules in RTAs have significantly influenced the trade structures of member countries. Some research finds that stringent environmental provisions can suppress exports of pollution-intensive goods while promoting exports of environmentally friendly products, with particularly pronounced effects on developing countries (Brandi et al., 2020; Fu and Cao, 2023). Other studies suggest that environmental provisions may reduce overall trade volume (Berger et al., 2020), yet simultaneously stimulate green technological innovation and improve product quality, thereby fostering the growth of exports of environmentally friendly products (Xie et al., 2023; Zhu and Sun, 2025). Trade policies significantly affect the fisheries and aquaculture sector; environmental provisions in RTAs aim to mitigate the negative impacts of trade liberalization on this sector, although their effectiveness has not been quantitatively assessed (Bayramoglu et al., 2023).

Crucially, most existing literature focuses on manufactured goods or aggregate trade, with relatively few studies addressing specific agricultural or food products. In particular, empirical analyses on sectors like fisheries and aquaculture—characterized by dual attributes of resource utilization and ecological conservation—are especially scarce. Moreover, the majority of studies operate at the country level and fail to examine how different types of environmental provisions differentially affect trade in specific products (Santika et al., 2025). Therefore, it is difficult to accurately identify the actual mechanisms

through which environmental regulations affect China’s exports of highly sensitive agricultural products.

To address this gap, this paper aims to examine the impact of the depth of environmental provisions in major RTAs involving China on its aquatic product trade. The study first constructs a quantitative method of environmental provisions in China’s RTAs, adopting the scoring method based on coverage dimensions proposed by Berger et al. (2017). Second, we employ an extended gravity model of trade, incorporating aquatic product trade data from China. Finally, it differentiates among various types of environmental provisions to identify their heterogeneous effects on aquatic product trade. It is hoped that this research will provide useful insights for supporting the sustainable development of the fisheries and aquaculture sectors.

Our approach advances the literature in three ways. First, we classify environmental provisions into restrictive and facilitative categories based on their legal functions, enabling a more nuanced assessment of their differential impacts. Second, we reveal that the effects of these provisions are significantly stronger in trade relationships with geographically distant and high-income partners—highlighting the moderating roles of distance and development level. Third, our findings offer actionable insights for designing differentiated strategies as China deepens its participation in international trade negotiations, particularly in balancing economic competitiveness with environmental sustainability.

The remainder of this paper is organized as follows: Section 2 reviews the literature and theoretical hypotheses; Section 3 describes empirical model specification and the data sources; Section 4 reports the baseline regression results and robustness checks; Section 5 conducts heterogeneity analysis; and Section 6 concludes.

2 Literature review and theoretical hypothesis

2.1 Literature review

As global attention to sustainable development has intensified, the inclusion of environmental provisions in RTAs has become a prominent trend in international economic and trade cooperation. Baghdadi et al. (2013) argue that such provisions are introduced to address the negative environmental impacts with trade. A growing body of literature has examined the role of environmental provisions in RTAs and their effects on economic, focusing primarily on trade flows, environmental protection, and export product quality.

First, regarding trade flows, some studies suggest that environmental provisions in RTAs may exert a dampening effect on bilateral trade. Through empirical analysis of a multi-country panel dataset, Brandi et al. (2020) find that RTAs with a greater number of environmental provisions are associated with lower trade volumes among signatories, with this negative impact being particularly pronounced for developing countries. This phenomenon is interpreted as a manifestation of “green protectionism,” whereby developed countries impose stringent environmental standards to restrict imports from developing nations, thereby protecting domestic industries. It is further argued that lower environmental standards constitute a comparative advantage for developing countries (Bernauer and Nguyen, 2015). Similarly, studies focusing on China indicate that deeper

environmental provisions exert a stronger suppressive effect on exports of energy-intensive products (Xu and Jiang, 2023; Yue and Lin, 2024). These findings suggest that environmental provisions not only affect overall trade volume but may also impose structural shocks on specific industries.

Second, research on environmental outcomes investigates whether environmental provisions in RTAs contribute to reduced carbon emissions or improved resource efficiency. Some studies argue that RTAs containing strong environmental commitments can encourage signatory countries to strengthen environmental governance, thereby lowering carbon emission intensity or pollution levels per unit of GDP (Ul Hassan et al., 2024; Wang et al., 2024; Baghdadi et al., 2013). Martínez-Zarzoso and Oueslati (2018) analyzing 29 OECD countries, find that RTAs with environmental provisions are associated with lower PM_{2.5} concentrations. This result holds when extending the sample to 173 countries and considering other pollutants such as carbon dioxide and nitrogen dioxide. However, other studies suggest that environmental provisions in RTAs may enable developed countries to engage in “environmental footprint offshoring”, shifting resource consumption and pollution to developing countries, thereby reducing domestic environmental pressures—a phenomenon known as “environmental impact transfer.” This process widens the gap in resource use between high-income and low-income countries, contributing to global inequality in resource distribution and economic development (Santika et al., 2025). Nevertheless, some scholars contend that in the absence of effective enforcement mechanisms, environmental provisions often remain symbolic and fail to yield tangible environmental benefits (Yu et al., 2024).

Third, firm-level analyses explore how environmental provisions affect export product quality. Zhu and Sun (2025), using firm-level data from China, find that stricter environmental provisions in RTAs incentivize firms to enhance production technologies and management capabilities, leading to improvements in export product quality. This suggests that while environmental rules may impose short-term cost pressures, they can also stimulate long-term technological upgrading and structural optimization.

Importantly, environmental provisions in RTAs are highly heterogeneous in design and legal force. A growing consensus classifies them into procedural and substantive types (Morin et al., 2018). Procedural clauses aim to build capacity and reduce information barriers without imposing binding obligations. In contrast, substantive clauses establish enforceable commitments, which may raise compliance costs for exporters. Building on this paper, Brandi et al. (2020) classify environmental provisions into trade-restrictive and liberal types to analyze their differential effects on trade, particularly across countries with differing regulatory capacities.

Despite these insights, critical gaps remain. Most existing studies focus on aggregate trade flows or energy-intensive manufacturing sectors, with limited in-depth analysis of resource-dependent industries such as agriculture and fisheries. In particular, for economies like China—both a major producer and exporter of aquatic products—there remains a lack of systematic empirical research on how environmental provisions specifically affect its aquatic products trade. Moreover, most studies treat environmental provisions as a single, undifferentiated variable, failing to distinguish the heterogeneous impacts of different types of provisions (e.g., restrictive versus facilitative), thereby limiting the precision of policy implications.

Parallel to this, dedicated research on aquatic product trade remains scarce. Existing studies primarily examine the relationship

between fisheries and aquaculture and issues such as climate change, circular economy, and sustainable development (Singh and Sarma, 2025; Abeysinghe et al., 2025; Osei et al., 2025). Bayramoglu et al. (2023) investigate the impact of fisheries-related provisions (FRPs) in trade agreements on the sustainability of marine fishery resources, analyzing 726 RTAs from 1947 to 2018 and global mean trophic level (MTL) data from 1950 to 2018. They find that RTAs have a negative impact on marine fishery resources, as reflected in declining MTL, indicating resource degradation due to trade liberalization. However, RTAs that include FRPs partially offset this negative effect, stabilizing MTL in signatory countries and preventing unsustainable “fishing down the food web” trends. While FRPs achieve environmental goals related to fishery sustainability, they may conflict with the core objective of RTAs—trade liberalization—since FRPs function by restricting trade opportunities in aquatic products, potentially increasing export costs for developing countries and creating implicit trade barriers.

Importantly, the existing literature primarily focuses on RTAs led by Western economies, while revealing the impact and mechanisms of environmental provisions on aquatic product trade, largely overlooks the role of emerging economies such as China in green trade governance. Although China is the world's leading aquaculture producer and a pivotal actor in Belt and Road Initiative (BRI)-linked RTAs, its agreements typically contain relatively weak environmental provisions, and domestic regulation of aquaculture's environmental externalities remains underdeveloped (Fang and Asche, 2021). More importantly, few studies on fishery and aquaculture trade have analyzed the content of RTAs involving China, nor have they differentiated or compared various types of environmental provisions, making it difficult to accurately identify which specific clauses truly influence China's aquatic product trade behavior. Moreover, due to its heavy reliance on natural resources, high vulnerability to climate change, and long industrial supply chain, this sector may be significantly more sensitive to environmental regulations than other industries. Therefore, we need more research on how environmental provisions affect China's aquatic product trade.

In summary, the existing literature exhibits two major gaps. First, there is a lack of empirical studies that link environmental provisions in RTAs to aquatic product trade. Second, it fails to distinguish the heterogeneous effects of different types of environmental provisions, hard to give detailed policy advice.

Addressing these gaps, this paper makes three key contributions. First, it provides the systematic analysis of how environmental provisions in RTAs affect China's aquatic product trade. While Bayramoglu et al. (2023) assess the global ecological impact of FRPs, they do not examine country-specific trade responses. Our study leverages China's unique position as the world's top aquatic product exporter to generate empirically grounded insights. Second, we refine the classification of environmental provisions by distinguishing between trade-restrictive and trade-facilitative types based on their legal function and economic intent. Although Bayramoglu et al. (2023) differentiate FRPs into enforceable and cooperative categories and find the former more effective for conservation, they do not test their direct impact on trade flows. In contrast, our framework explicitly links provision type to trade outcomes. Third, we investigate how the effects of environmental provisions vary across trading partners with different geographic distances and income levels. This heterogeneity analysis highlights the moderating roles of proximity and development status, offering a foundation for designing differentiated negotiation strategies in China's future RTA engagements.

2.2 Theoretical hypothesis

Base on the literature review and identified research gaps, this paper proposes the following theoretical hypotheses to examine the mechanisms through which environmental provisions in RTAs affect China's aquatic product trade.

Hypothesis 1: The depth of environmental provisions in RTAs significantly influences China's aquatic product trade flows.

Hypothesis 2: The trade effects of environmental provision depth in RTAs may vary depending on partner countries' geographic distance and income levels.

Existing studies suggest that the inclusion of environmental provisions often increases firms' compliance costs, particularly in RTAs with high environmental standards, where exporters must invest more in pollution control, clean production, and certification processes (Xu and Jiang, 2023). In the fishery and aquaculture sector, these costs may manifest in areas such as wastewater treatment in aquaculture, environmentally friendly feed standards, restrictions on fishing methods, and requirements for biodegradable packaging materials. If firms fail to adapt to these new requirements in a timely manner, they may face export disruptions or loss of orders, leading to a decline in overall trade volume. Furthermore, certain environmental provisions may directly restrict the import or export of products deemed environmentally high-risk, such as seafood obtained through destructive fishing practices or derived from illegal, unreported, and unregulated (IUU) fisheries. Such restrictive measures would further constrain export opportunities for affected products. Therefore, it is expected that as the number, scope, and enforce ability of environmental provisions in RTAs increase, China's aquatic product trade with partner countries may experience a negative impact. Besides, the trade impact of these provisions is likely to vary with partner countries' income levels or geographic distance, as trade cost differ across country. This hypothesis draws on prior research on the trade-inhibiting effects of environmental provisions on energy-intensive exports (Zhu and Sun, 2025; Xu and Jiang, 2023).

Hypothesis 3: The impact of environmental provisions on China's aquatic product trade varies by type, with restrictive provisions exerting a stronger effect on trade than facilitative provisions.

Not all environmental provisions have equivalent trade effects. Based on their functional orientation, these provisions can be categorized into restrictive and facilitative types. Restrictive provisions typically take the form of prohibitions or mandatory standards, such as bans on specific fishing gear, seasonal fishing restrictions, requirements for sustainable fisheries certification, or prohibitions on importing products made from endangered species. These provisions directly raise trade barriers, increase compliance burdens, and elevate operational costs, making them more likely to generate adverse trade effects. In contrast, facilitative environmental provisions focus on promoting environmentally friendly trade through measures such as green technology cooperation and support for eco-aquaculture projects. While these provisions also involve environmental regulation, their objective is incentivization rather than restriction, and they may promote sustainable trade by reducing transaction costs for green products or opening new markets. Consequently, we think that restrictive

provisions will have a significantly stronger negative impact on China's aquatic product exports compared to facilitative provisions, and in some cases, the latter may even exert a positive effect on exports. This distinction reflects the dual realities of "green protectionism" and "green cooperation" in global trade (Bernauer and Nguyen, 2015; Yao et al., 2019) and builds on Zhu and Sun's (2025) insight that environmental pressure can be transformed into a driver of quality upgrading.

In sum, this paper will empirically test the above hypotheses to address existing gaps in the literature regarding sectoral specificity and provision classification, aiming to provide theoretical insights and policy implications for China's participation in high-standard RTA negotiations and the enhancement of its international competitiveness in aquatic product trade.

3 Empirical methodology and data

3.1 Empirical strategy

The empirical approach in this study follows the methodology of Baghdadi et al. (2013) and Zhu and Sun (2025), employing a two-way fixed-effects panel data model to identify the net effect of environmental provision depth on aquatic product trade. The baseline model is specified as:

$$\ln(\text{trade}_{jt}) = a_0 + a_1 \text{ENV}_{jt} + \beta X_{jt} + \theta_t + \theta_j + \varepsilon_{jt} \quad (1)$$

As shown in Equation (1), i denotes the country China, j denotes the trading partner country, and t denotes the year.

The dependent variable, $\ln(\text{trade}_{jt})$, represents the logarithmic value of China's aquatic product exports or imports to country j in year t , expressed in natural logarithm to mitigate heteroskedasticity.

The key explanatory variable, ENV_{jt} , measures the depth of environmental provisions in RTAs between China and the trading partner country j . This variable capture both the breadth of coverage and the strength of legal enforceability of environmental provisions within the agreement. The coefficient α_1 is expected to be negative, as stricter environmental provisions may raise compliance costs and technical barriers for exporters, thereby constraining aquatic product trade. However, such provisions could also enhance product quality and international reputation, generating positive effects. The empirical results will reveal the net impact.

The vector of control variables, X_{jt} , includes the logarithmic values of GDP of China and the trading partner to reflect market size; The logarithmic value of geographic distance and a dummy for common border to capture transport costs; a dummy for shared language as a proxy for cultural and institutional proximity; and the environmental regulation stringency of the trading partner country to account for the potential influence of domestic environmental policies on trade flows.

To address unobserved heterogeneity, the model includes time fixed effects (θ_t) and individual fixed effects (θ_j), which control for time-varying country-level factors that could affect trade. This helps mitigate endogeneity concerns arising from omitted variables (Baier and Bergstrand, 2007).

The error term ε_{jt} is assumed to be independently and identically distributed, with standard errors clustered at the country-pair level to account for potential serial correlation.

3.2 Data and sources

This study examines the impact of environmental provisions in RTAs on China's aquatic product trade. We constructed a panel data covering 47 countries or region that traded aquatic products with China during the period 2000–2019 to capture the impact. Among them, 10 countries or region that have signed and implemented RTAs with China form the treatment group, including ASEAN¹, Australia, New Zealand, Chile, South Korea, Pakistan, Singapore, Peru, Iceland, and Hong Kong. The remaining countries serve as the control group. This time frame is selected because it coincides with China's increasing participation in RTAs, many of which include comprehensive environmental chapters, enabling the observation of the actual effects of environmental provisions. We acknowledge that more recent geopolitical and policy shifts may affect current trade dynamics. However, our core mechanism is likely to remain relevant.

3.2.1 The dependent variable

The dependent variable ($\ln(\text{trade}_{it})$) is bilateral trade in aquatic products between China and its RTA partner countries, measured separately by export and import values. These two dimensions are chosen because they directly reflect China's foreign trade performance in the aquatic sector. Export value indicates China's competitiveness and market share in the global market, while import value reflects domestic demand and reliance on external resources. Since environmental provisions may affect both imports and exports, analyzing them separately allows for a more comprehensive understanding of their trade impacts.

Fishery and aquaculture products are defined according to the statistical classification of the FAO (FAO and WCO, 2023). The scope includes Chapter 3 of the Harmonized System (HS) codes (fish, crustaceans, mollusks, and other aquatic invertebrates) and relevant products from other chapters. This ensures accuracy and comparability of the variable. We first identify aquatic products using HS-6(HS1996) codes, then aggregate their bilateral trade flows to the country-pair-year level for empirical analysis. Trade data for the 2000–2019 period are sourced from the CEPII-BACI database, which provides detailed bilateral trade data classified by HS codes.

3.2.2 The core explanatory variable

The core explanatory variable (ENV_{jt}) is the depth of environmental provisions in RTAs. Following Brandi et al. (2020) and Baghdadi et al. (2013), this study argues that merely examining whether an environmental chapter exists is insufficient to capture its real influence. Instead, the depth of provisions—defined by their legal bindingness, specificity, enforcement mechanisms, and scope of coverage—better reflects their actual effectiveness. A higher number of provisions indicates broader coverage of environmental issues and clearer regulatory or promotional intent, making depth a more precise measure than a simple binary dummy. Accordingly, this study uses the absolute

number of environmental provisions in each RTA as the measure of depth.

Data on environmental provisions are drawn from the Trade and Environment Database (TREND), developed by Morin et al. (2018). TREND is a comprehensive and granular database designed to identify and code environmental clauses in regional trade agreements. Based on the Design of Trade Agreements (DESTA) project, which collects 726 RTAs, researchers conduct manual content analysis on each agreement to identify environment-related clauses, classify them, and assign scores. Beyond mere presence/absence, TREND quantifies provisions using indicators such as clause count, commitment strength, and enforcement mechanisms, providing reliable support for this study. The database covers data up to 2018, which we extend to 2019.

Existing studies suggest that relying solely on the total number of environmental provisions may obscure their true impact on trade flows. Different types of provisions, due to divergent policy goals and mechanisms, may exert opposing effects on trade structure. Ignoring this significant heterogeneity may lead to biased estimates (Brandi et al., 2020; Bastiaens and Postnikov, 2017). Lechner (2018) finds that environmental provisions affect FDI differently across sectors, discouraging polluting industries while encouraging clean ones; Baccini (2017) show that the interaction between PTA depth and provisions type influences trade diversion.

Building on this, and following Brandi et al. (2020)'s classification framework based on TREND, this study categorizes environmental provisions into two types based on their trade impact direction and policy objective. We classify environmental provisions into two types, Trade-restrictive provisions (ENVRES_{jt}) aim to limit environmentally harmful trade and may increase trade costs for polluting sectors. Trade-facilitative provisions (ENVLIB_{jt}) promote environmentally beneficial trade and may reduce trade barriers for green goods.

3.2.3 Control variable

Following Baghdadi et al. (2013) and Baier and Bergstrand (2007), we select the variables from the standard gravity model as control variables include:

GDP of China and the trading partner ($\ln\text{GDP}_{it}$, $\ln\text{GDP}_{jt}$), used to measure market size, sourced from the World Bank's World Development Indicators (WDI) database and expressed in current USD, then logged.

Geographic distance ($\ln\text{Dist}_{jt}$), defined as the spherical distance between capital cities, expressed in natural logarithm. A dummy for common border (Contig_{jt}), equal to 1 if countries share a land border, 0 otherwise. Greater distance and lack of a shared border are expected to raise transportation costs and negatively affect trade. A dummy for common language (ComLang_{jt}), set to 1 if countries share an official language or widely spoken common language, 0 otherwise, serving as a proxy for cultural proximity and communication ease. These data are obtained from the CEPII Gravity Database (Conte et al., 2022).

Partner's environmental regulation stringency (EnvReg_{jt}), proxied by the Environmental Performance Index (EPI) jointly developed by Yale University's Center for Environmental Law and Policy and Columbia University's Center for International Earth Science Information Network. The EPI aggregates 58 performance indicators across 11 policy categories, including climate change, environmental health, and ecosystem vitality, offering a comprehensive assessment of national progress toward environmental goals. It effectively captures the overall strictness and enforcement capacity of a country's

¹ The ASEAN sample includes all member countries except Singapore, Brunei, Cambodia, and Laos. Singapore is excluded due to the existence of a separate bilateral free trade agreement with China (the China–Singapore FTA), which is treated separately in our analysis. Brunei, Cambodia, and Laos are excluded owing to missing data on key variables over the sample period.

environmental policy. We expect a negative relationship between EnvReg and trade values. Using EPI as a proxy helps control for the impact of destination countries' environmental stringency on trade flows (Block et al., 2024). Data are sourced from the Yale EPI database.

To isolate the effect of environmental provisions from general RTAs effects, this study includes a variable measuring the overall depth of the trade agreement ($Depth_{jt}$). This variable captures the extent to which RTAs cover behind-the-border policy areas. Following Dür et al. (2014), the raw index is standardized using the formula: $(\text{original value} - \text{minimum value}) / (\text{maximum value} - \text{minimum value})$. A higher standardized value indicates deeper integration and broader coverage of behind-the-border measures. This data comes from the DESTA database.

Additionally, the model controls for time and partner-country fixed effects (θ_i, θ_j) to absorb the influence of unobserved, time-invariant characteristics of partner countries. The random error term ε_{ijt} is assumed to be independently distributed, with standard errors clustered at the country-pair level to enhance estimation robustness.

3.3 Descriptive statistics

Table 1 reports the descriptive statistics for the main variables as following.

The sample consists of 940 trade observations from 47 countries or regions over the period 2000–2019, covering 20 years. Summary statistics for key variables are presented in Table 1. The natural logarithms of export value ($\ln \text{Export}_{jt}$) and import value ($\ln \text{Import}_{jt}$) have mean values of 9.560 and 9.780, with standard deviations of 3.290 and 2.570, respectively, indicating substantial variation in trade volumes. The depth of environmental provisions (ENV_{jt}) has a mean of 2.740 and a maximum value of 72, reflecting both richness and uneven distribution of environmental provisions across RTAs. The means of facilitative ($ENVLIB_{jt}$) and restrictive ($ENVRES_{jt}$) provisions are 1.200 and 1.550, respectively, suggesting that restrictive provisions dominate. The overall depth of RTAs ($Depth_{jt}$) has a mean of 0.110 and a standard deviation of 0.320, indicating significant variation in the breadth of agreement coverage. The GDP of trading partners and China ($\ln \text{GDP}_{jt}$, $\ln \text{GDP}_{it}$)

have mean values of 19.46 and 22.29, while the natural logarithm of geographic distance ($\ln \text{Dist}_{jt}$) has a mean of 8.890, both showing high dispersion. The dummy variables for common border and common language (Contig_{jt} , ComLang_{jt}) have means of 0.130 and 0.060, respectively, indicating that most trading partners share neither a land border nor a common language with China. The environmental regulation stringency of trading partner countries (EnvReg_{jt}), measured by the EPI, has a mean of 59.46 and a standard deviation of 12.55, reflecting considerable cross-country differences in environmental policy levels.

4 Empirical results

4.1 Baseline estimates

This study employs an extended gravity model to examine the impact of environmental provisions depth in RTAs on China's bilateral aquatic product trade flows. The baseline regression results are presented in Table 2. Columns (1)–(4) use the logarithm of China's aquatic product imports as the dependent variable, while columns (5)–(8) use the logarithm of exports. Control variables and fixed effects are progressively introduced across columns to enhance estimation robustness.

4.1.1 Effects on import trade

In column (1), the coefficient on environmental provisions depth is 0.074 and significant at the 1% level, indicating that deeper environmental provisions in RTAs are associated with higher aquatic product imports from partner countries.

In column (2), after controlling for core gravity variables—China's and partner countries' GDP and geographic distance—the coefficient on environmental provisions depth decreases slightly to 0.070 but remains highly significant. This suggests that the positive effect of environmental provisions depth on imports persists and remains

TABLE 1 Descriptive statistics of variables.

Variable	Definition	Data sources	Observations	Mean	Std. dev.	Min	Max
$\ln \text{Export}_{jt}$	Export value (log)	CEPII-BACI	940	9.560	3.290	−2.810	15.410
$\ln \text{Import}_{jt}$	Import value (log)	CEPII-BACI	940	9.780	2.570	−2.780	15.040
ENV_{jt}	RTA environmental provision depth	TREND	940	2.740	10.120	0	72
$ENVLIB_{jt}$	RTA facilitative provision depth	TREND	940	1.200	3.720	0	21
$ENVRES_{jt}$	RTA restrictive provision depth	TREND	940	1.550	6.650	0	51
$Depth_{jt}$	RTA depth	DESTA	940	0.110	0.320	0	1
$\ln \text{GDP}_{jt}$	Trading partner GDP (log)	WDI	940	19.460	1.750	15.030	23.790
$\ln \text{GDP}_{it}$	China's GDP (log)	WDI	940	22.290	0.840	20.900	23.380
$\ln \text{Dist}_{jt}$	Geographic distance in kilometers (log)	CEPII gravity	940	8.890	0.730	6.5300	9.880
Contig_{jt}	Common border dummy	CEPII gravity	940	0.130	0.330	0	1
ComLang_{jt}	Common language dummy	CEPII gravity	940	0.060	0.240	0	1
EnvReg_{jt}	Trading partner's environmental regulation stringency	EPI by Yale	906	59.460	12.550	25.610	90.510

For ASEAN (excluding Singapore, Brunei, Cambodia, and Laos—i.e., the remaining seven member countries), trade and GDP values are summed across the seven countries. Distance is calculated as the average of the seven countries' distances to China. Contiguity is coded as 1 (adjacent) if any of the seven countries shares a land border with China; common official language is coded as 0 (no common language). Environmental regulation data are missing for Hong Kong and Uganda for the years 2000–2013.

robust even after accounting for fundamental economic-geographic factors such as market size and transport costs. Additionally, the coefficients on both China's and partner countries' GDP are significantly positive, confirming that bilateral economic size is a key driver of import growth. The coefficient on bilateral distance is also significantly positive, which contradicts the prediction of the standard gravity model and implies that China's aquatic product imports are highly dependent on specific natural fishery resources or large-scale aquaculture capacity in certain countries. Furthermore, the dummy variables for common border and common language have significantly positive coefficients, as expected, indicating that geographic proximity and cultural-linguistic similarity still positively influence imports.

In column (3), time fixed effects are added to control for time-varying shocks. The coefficient on environmental provisions depth remains unchanged and continues to be significant at the 1% level, suggesting that the positive import effect is not driven by external macro trends but is inherent in the RTA institutional framework itself.

However, in column (4), when both time and individual fixed effects are included, the coefficient on environmental depth turns negative (-0.011) and becomes significant at the 5% level. This indicates that after controlling for additional potential confounders, the initially observed positive effect weakens and even reverses. To interpret this effect in economically meaningful terms, we consider a shift from no environmental provisions (ENV = 0) to the 90th percentile of observed

depth (ENV = 5). This change corresponds to an estimated 5.5% reduction in imports, compared to country pairs with similar initial import volumes and agreement depth. This shift may reflect the presence of a "green barrier" effect: although environmental provisions may promote market openness, their accompanying stringent standards could raise import thresholds, making it difficult for low-quality or high-pollution products to enter, thereby suppressing overall import volumes.

4.1.2 Effects on export trade

Regarding exports, column (5) shows that the coefficient on environmental provisions depth is 0.027 and significant at the 1% level, indicating a positive association between the depth of RTAs environmental provisions and China's aquatic product exports.

In column (6), after introducing control variables, the coefficient on environmental depth is 0.011 and significant at the 5% level. This confirms that, after adjusting for bilateral economic size, geographic distance, and cultural-geographic factors, deeper environmental provisions in RTAs are linked to higher Chinese exports. This provides initial support for the "green cooperation" hypothesis, suggesting that environmental provisions may facilitate market access and trade facilitation. The coefficients on variables representing bilateral economic size are significantly positive, confirming the importance of market scale. The coefficients on distance and

TABLE 2 Baseline regression results.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	lnImport _{jt}	lnImport _{jt}	lnImport _{jt}	lnImport _{jt}	lnExport _{jt}	lnExport _{jt}	lnExport _{jt}	lnExport _{jt}
ENV _{jt}	0.074*** (14.11)	0.070*** (9.18)	0.070*** (3.39)	-0.011** (-2.05)	0.027*** (4.21)	0.011** (2.38)	0.013 (1.14)	0.004 (0.28)
Depth _{jt}		-0.429 (-1.10)	-0.413 (-0.38)	0.644*** (3.35)		0.122 (0.50)	-0.131 (-0.21)	-0.913 (-1.13)
lnGDP _{it}		0.365*** (3.74)				0.415*** (5.05)		
lnGDP _{jt}		0.614*** (14.91)	0.610*** (3.90)	0.676* (1.91)		1.234*** (36.39)	1.207*** (10.94)	2.007*** (5.70)
LnDist _{it}		0.276** (2.19)	0.275 (0.68)			-0.862*** (-9.02)	-0.867*** (-2.72)	
Contig _{it}		1.442*** (6.15)	1.478 (1.55)			-1.098*** (-4.47)	-0.898 (-0.90)	
ComLang _{it}		0.887** (2.53)	0.884 (0.80)			0.448* (1.88)	0.421 (0.51)	
EnvReg _{it}		-0.004 (-0.63)	-0.002 (-0.08)	-0.002 (-0.10)		0.041*** (7.43)	0.053** (2.36)	-0.031* (-1.80)
Constant	9.574*** (112.69)	-12.933*** (-5.18)	-4.850 (-0.94)	-3.289 (-0.44)	9.483*** (84.47)	-18.405*** (-9.25)	-9.288** (-2.24)	-27.725*** (-4.09)
Observations	940	906	906	906	940	906	906	906
R-squared	0.084	0.317	0.323	0.886	0.007	0.717	0.725	0.924
Partner-country FE	No	No	No	Yes	No	No	No	Yes
Year FE	No	No	Yes	Yes	No	No	Yes	Yes

In columns (3)-(4) and (7)-(8), lnGDP_{it} is omitted due to time fixed effects. In columns (4) and (8), LnDist_{it}, Contig_{it}, and ComLang_{it} are excluded because they are time-invariant and fully absorbed by the combination of time and partner-country fixed effects. Robust t-statistics in parentheses ***p < 0.01, **p < 0.05, *p < 0.1.

common language align with expectations, indicating that China's exports are significantly affected by trade costs. Meanwhile, the coefficient on the importing country's environmental regulation stringency is 0.041 and significantly positive, implying that stricter domestic environmental policies in destination countries promote China's exports.

In columns (7) and (8), after sequentially adding time fixed effects and importer fixed effects, the coefficient on environmental provision depth loses statistical significance. This suggests that the initially observed positive effect of RTA environmental depth on China's aquatic product exports is not robust and may stem from unobserved time-specific shocks or structural characteristics of importing countries. Once these factors are controlled for, the net effect of environmental provisions on export volumes diminishes, indicating limited trade-promoting power at the current stage. The coefficient on the environmental regulation variable remains significant but change from positive (0.053) to negative (−0.031). The sign reversal suggests that once we account for endogeneity, stricter domestic environmental regulations in importing countries are negatively associated with Chinese exports—consistent with the view that such regulations raise compliance costs for foreign exporters.

Overall, the baseline regression results reveal a complex picture of how RTAs environmental provisions depth affects aquatic product trade. For imports, while initial estimates show a significant positive effect, this effect vanishes or even turns negative after including more controls, suggesting a potential restraining role through higher entry barriers. For exports, environmental depth shows a positive effect in basic models, but this effect disappears once fixed effects are introduced, indicating that its influence may depend on other unobserved moderating factors. In contrast, the environmental regulation stringency of trading partners consistently exerts a significant negative effect in models, underscoring that unilateral environmental policies act as more substantive trade barriers than multilateral environmental clauses in RTAs.

4.2 Robustness checks

To ensure the reliability of the baseline results, this paper conducts multiple robustness checks from the perspectives of estimation methods, sample selection, dynamic effects, and endogeneity. We have now examined potential multicollinearity by computing variance inflation factors (VIFs) for basic regressions. The mean VIF is 1.41 (maximum = 1.59), well below the commonly used threshold of 5, indicating that multicollinearity is not a concern.

4.2.1 PPML method

The model is re-estimated using the Poisson pseudo-maximum likelihood (PPML) method. Given the presence of numerous zero values and heteroskedasticity in aquatic product trade data, ordinary least squares (OLS) may yield biased and inconsistent estimates. Following [Timsina and Culas \(2020\)](#), PPML estimation is employed, which effectively handles zero trade flows, avoids biases caused by logarithmic transformation, and performs well in gravity models with small samples. We estimate PPML models with trade flows in levels and cluster standard errors at the partner-country level to address overdispersion. The results are reported in columns (1) and (2) of [Table 3](#). For both imports and exports, the sign and significance of the coefficient on the key variable—environmental provisions

depth—remain consistent with the baseline findings, indicating that the conclusions are robust to the choice of estimation method.

4.2.2 Add lagged term

The lagged effects of environmental provisions are examined. The impact of environmental provisions in RTAs often exhibits time lags, as rule transmission, firm adaptation, and market adjustment require time. To better identify the dynamic path of policy effects, first-order lagged terms (ENV_{jit-1}) and second-order lagged terms (ENV_{jit-2}) of environmental provisions depth are introduced into the model. As shown in columns (3) and (4) of [Table 3](#), we find the coefficient on ENV_{jit-2} is significantly negative in the import equation, indicating that the restraining effect on imports becomes more pronounced over time. In the export equation, however, the lagged terms are insignificant, suggesting limited and non-persistent effects. These results support the existence of a “green barrier” effect and reveal its delayed nature.

4.2.3 Add leading term

Third, potential endogeneity due to reverse causality is addressed. Countries with larger trade volumes may be more likely to negotiate RTAs with deeper environmental provisions, potentially biasing the estimated effect of ENV_{jit} . To test for this endogeneity issue, following [Baier and Bergstrand \(2007\)](#), the lead term of ENV_{jit} (ENV_{jit+1})—the future value of environmental provision depth—is included to explain current trade flows. If ENV_{jit+1} is significant, it would suggest that current trade levels anticipate future institutional arrangements, reflecting either anticipation effects or selective treaty formation. As shown in columns (5) and (6) of [Table 3](#), the coefficients on ENV_{jit+1} are not significant, indicating weak evidence of reverse causality and supporting the plausibility of the core explanatory variable's exogeneity.

4.2.4 Add quadratic terms

To address the possibility of nonlinear effects of environmental provisions on trade flows, we extend our baseline specification by including a quadratic term of the environmental provisions (ENV^2). As shown in Columns (7) and (8) of [Table 4](#), neither the linear term nor the quadratic term is statistically insignificant for either imports or exports. The estimates suggest a weakly concave relationship but the imprecision of the estimates precludes strong conclusions. These findings indicate that the impact of environmental provisions depth on bilateral trade consistent with an approximately linear relationship.

4.2.5 Instrumental variable method

Instrumental variable estimation is employed to test and correct for endogeneity. To further address potential endogeneity, this study follows [Baier and Bergstrand \(2007\)](#) in constructing instrumental variables: the depth of environmental provisions in RTAs between partner countries and all other countries except China ($Envother_{jht}$), and the first-order lagged term of environmental provision depth (ENV_{jit-1}). These instruments satisfy relevance by influencing the diffusion of environmental regulations, and are subject to exclusion restrictions by not directly affecting bilateral trade with China, but only indirectly through domestic policy channels. The two-stage least

TABLE 3 Robustness checks.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Import _{jt}	Export _{jt}	lnImport _{jt}	lnExport _{jt}	lnImport _{jt}	lnExport _{jt}	lnImport _{jt}	lnExport _{jt}
	PPML	PPML	Lagged term	Lagged term	Leading term	Leading term	Quadratic terms	Quadratic terms
ENV _{jt}	−0.009*** (−3.30)	−0.002 (−1.36)	−0.007** (−2.18)	−0.009 (−1.08)	−0.006 (−1.51)	0.013 (0.91)	−0.015 (−0.66)	0.049 (1.33)
ENV _{jt-1}			0.002 (0.78)	0.001 (0.33)				
ENV _{jt-2}			−0.007* (−1.80)	0.009 (0.96)				
ENV _{jt+1}					−0.004 (−1.51)	−0.008 (−1.25)		
ENV ²							0.000 (0.23)	−0.001 (−1.61)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	906	906	816	816	860	860	906	906
R-squared	0.9512	0.9820	0.903	0.932	0.892	0.928	0.887	0.927
Partner-country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust z-statistics in parentheses ****p* < 0.01, ***p* < 0.05, **p* < 0.1.

squares (2SLS) regression results are presented in Table 4. The Kleibergen-Paap rk LM test for under-identification yields a *p*-value less than 0.1, indicating no weak identification problem. The Cragg-Donald Wald F statistic exceeds 19.93, rejecting the hypothesis of weak instruments. In the second stage, the coefficient on environmental provisions depth remains significantly negative in the import equation and insignificant in the export equation, consistent with the baseline results, confirming the robustness of the findings after accounting for endogeneity.

5 Heterogeneity checks

Beyond examining the overall effects, it is essential to consider variations across different contexts. To this end, this study conducts heterogeneity analysis based on the baseline regressions, performing subgroup tests along three dimensions: type of environmental provisions, geographic distance, and income level of trading partners, aiming to provide a more comprehensive understanding of the actual mechanisms through which environmental provisions operate. The results are presented in Table 5.

First, columns (1) to (4) examine the net effects of two types of environmental provisions. The coefficient on trade-facilitative provisions (ENVLIB_{jt}) is insignificant across all models and close to zero, indicating that these provisions—designed to promote green trade—have limited impact on China’s aquatic product trade. This may be because such provisions are largely non-binding and emphasize voluntary cooperation, resulting in weak real trade effects. In contrast, trade-restrictive provisions (ENVRES_{jt}) yield a coefficient of −0.016 in the import model, significant at the

TABLE 4 Instrumental variable method.

Variables	(1)	(2)	(3)
	ENV _{jt}	lnImport _{jt}	lnExport _{jt}
ENV _{jt}		−0.012* (−1.93)	0.005 (0.33)
Envother _{jt}	−0.001 (−0.11)		
ENV _{jt-1}	0.839*** (12.20)		
Control variables	YES	YES	YES
Observations	861	861	861
R-squared	0.886	0.032	0.244
Partner-country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
K-P rk LM	4.833 (0.0892)		
C-D Wald F	938.18 >38.180 (19.93)		

Robust *t*-statistics in parentheses ****p* < 0.01, ***p* < 0.05, **p* < 0.1.

5% level, while being positive but insignificant in the export model. The coefficient is larger than the baseline estimate, indicating that restrictive provisions have a stronger dampening effect on trade.

Next, columns (5) to (8) present results from grouping by geographic distance. Columns (5) and (7) include short-distance trade samples, while columns (6) and (8) cover long-distance trade. The results show that the coefficient on environmental provision depth is insignificant in short-distance trade. In contrast, for long-distance trade, the coefficient is significantly negative (-0.014) in the import equation, with no notable effect in the export equation. This indicates that high logistics costs and time delays inherent in long transportation are further exacerbated by stringent environmental regulations, increasing exporters' compliance burden and leading exporting countries to reduce aquatic product exports to China. By comparison, in short-distance trade, where transport is convenient and information flows smoothly, the impact of environmental provisions is weakened and may even be mitigated through regional cooperation mechanisms.

Finally, columns (9) to (12) group observations by the income level of the partner country. Columns (9) and (11) include low-income countries, while columns (10) and (12) refer to high-income countries. In the high-income group, the coefficient on environmental provision depth is -0.046 in the import model, significant at the 1% level, and significantly negative (-0.009) in the export model. This reflects that high-income countries generally possess stronger environmental regulatory capacity and higher public environmental awareness, leading them to impose stricter ecological standards in RTAs, thereby creating substantial barriers to Chinese aquatic product trade. Specifically, we find that the effect of environmental provisions is statistically significant reduction in imports trade, suggesting that stricter environmental commitments act as a constraint on market access for exporters in these markets. In contrast, the effect on Chinese exports to low-income partners is positive but statistically insignificant, indicating no robust evidence of trade promotion in this group.

Overall, the impact of environmental provisions is not uniform but exhibits clear heterogeneity. Provisions designed to restrict pollution do act as trade barriers, particularly in high-income and long-distance markets. In contrast, green-promoting provisions currently exert little influence due to their weak enforceability.

6 Discussion and conclusion

6.1 Discussion

6.1.1 Main findings

Our results add to the literature on how environmental provisions in trade agreements affect trade flows, with a focus on a specific sector: fisheries and aquaculture. Most previous studies look at broad categories like manufacturing or all agricultural products, such as Brandi et al. (2020). In contrast, we examine only aquatic products, which face stricter environmental scrutiny due to concerns about illegal fishing, water pollution from farms, and product traceability. This specificity helps explain why we observe a pronounced negative effect of trade-restrictive environmental provisions on imports, whereas trade-facilitative provisions show little short-term impact—a pattern consistent with Brandi et al.'s finding that restrictive provisions suppress trade, but different from broader-sector studies that often report symmetric effects on exports and imports.

We find that deeper environmental provisions reduce imports of aquatic products into China, but do not significantly affect exports.

One possible reason is that China, as an importer, has started applying higher environmental standards to foreign suppliers, especially from countries with weak regulation. At the same time, Chinese exporters may have already adapted to similar standards in major markets, so environmental provisions do not hurt their exports much.

We also find that only trade-restrictive provisions reduce trade. The impact also depends on the trading partner. Environmental rules reduce imports more when the partner is far away or has high income. This makes sense that distant trade involves higher costs and more complex supply chains, so adding compliance requirements creates more burden. High-income countries also tend to enforce rules more strictly. In contrast, trade with nearby or lower-income partners is less affected, possibly because enforcement is weaker or regional coordination helps ease compliance.

Overall, our findings suggest that the effect of environmental provisions is not the same for all sectors or all countries. Focusing on a highly regulated sector like fisheries helps reveal patterns that might be hidden in broader analyses.

6.1.2 Compare with existing literature

Our findings differ with Brandi et al. (2020) and Berger et al. (2020), who find that environmental provisions generally reduce bilateral trade—especially exports from developing countries to high-income partners. It also differs from Yue and Lin (2024), who report a negative impact of such provisions on China's exports of energy-intensive manufactured goods. The divergence suggests that Chinese exporters in the fisheries sector may be less vulnerable due to stronger production capacity and prior adaptation to strict environmental standards in key markets.

Our heterogeneity analysis further shows that the import-reducing effect is stronger with high-income and distant partners, consistent with higher regulatory enforcement and compliance costs in these settings—a pattern broadly aligned with Berger et al. (2020) and Brandi et al. (2020). However, unlike their aggregate-level results, we find no significant export suppression, indicating that sector-specific characteristics matter. While Martínez-Zarzoso and Oueslati (2018) focus on environmental outcomes (e.g., PM_{2.5}), and Zhu and Sun (2025) examine quality upgrading, our analysis focuses exclusively on fisheries and aquaculture, a highly regulated and environmentally sensitive sector, where compliance costs and non-tariff barriers operate differently compared to broad manufacturing or agricultural aggregates.

6.1.3 Limitations and propose

Nonetheless, this study has certain limitations. First, it does not examine firm-level micro responses, such as potential differences in how firms of different ownership types (state-owned, private, foreign-invested) adjust production or export structures in response to environmental provisions. Second, it does not fully capture dynamic aspects of implementation—such as variations in actual enforcement intensity or dispute settlement cases—which may lead to under- or overestimation of the true impact of these provisions.

Future research could advance in several directions. First, integrating firm-level or product-level data with customs and business registration records could help analyze how environmental provisions affect export decisions, product quality upgrading, and technological innovation at the enterprise level. Second, applying text analysis methods to

TABLE 5 Heterogeneity analysis.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	lnImport _{jt}	lnImport _{jt}	lnExport _{jt}	lnExport _{jt}	lnImport _{jt}	lnImport _{jt}	lnExport _{jt}	lnExport _{jt}	lnImport _{jt}	lnImport _{jt}	lnExport _{jt}	lnExport _{jt}
ENVLIB _{it}	-0.030 (-1.32)		0.006 (0.16)									
ENVRES _{it}		-0.016** (-2.57)		0.006 (0.27)								
ENV _{it}					0.006 (0.26)	-0.014* (-1.79)	0.004 (0.37)	0.015 (0.86)	-0.018* (-1.86)	-0.046*** (-3.90)	0.026 (1.68)	-0.009** (-2.25)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	906	906	906	906	460	446	460	446	668	238	668	238
R-squared	0.887	0.887	0.925	0.925	0.878	0.905	0.955	0.925	0.861	0.941	0.896	0.955
Partner-country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust *t*-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

quantify enforcement strength could help construct more dynamic and operational indicators to better reflect differences in institutional quality.

7 Conclusion

This study analyzes how the depth of environmental provisions in RTA affects China's aquatic product trade using a gravity model and data from 2000 to 2019. It finds that deeper provisions—particularly trade-restrictive provisions—significantly reduce imports but not exports, with stronger effects in long-distance and high-income markets. Future work should incorporate firm- or product-level data to examine heterogeneous responses and enforcement dynamics.

Our analysis contributes by focusing on a sector where environmental rules directly affect market access. The results suggest that Chinese exporters have adapted well to green standards, while import screening has become stricter. This highlights the need for flexible negotiation strategies that pushing for high standards in developed markets, while supporting capacity building in developing ones.

In sum, as green trade rules continue to evolve globally, a deeper understanding of the mechanisms through which environmental provisions operate is not only crucial for industrial competitiveness but also central to China's strategic positioning in the ongoing restructuring of global value chains.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary material](#), further inquiries can be directed to the corresponding author.

Author contributions

YC: Data curation, Writing – original draft, Writing – review & editing. WC: Conceptualization, Writing – original draft, Writing – review & editing. XZ: Writing – original draft, Writing – review & editing.

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Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2026.1741505/full#supplementary-material>

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