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The Impact of Green Trade Barriers on China's Agricultural Exports: Evidence from 10 ASEAN Countries

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Abstract: This study uses panel data from 2005 to 2022, introduces relevant indicators of green trade barriers, and employs a stochastic frontier gravity model to examine the impact of green trade barriers on China's agricultural exports to ASEAN countries. At the same time, a trade inefficiency model is established to measure the trade efficiency and trade potential of China's agricultural exports. The results show that: (1) Green trade barriers inhibit China's agricultural exports. (2) Trade efficiency is obviously differentiated. Indonesia, the Philippines, and Thailand are among the top three countries with trade potential. Generally speaking, China needs to release its trade potential by deepening the mutual recognition of RCEP green standards, building an enterprise certification support system, and upgrading the cross-border logistics infrastructure.

Keywords: Green trade barriers; Agricultural exports; ASEAN-10 countries; Stochastic frontier gravity model; Trade inefficiency

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1. Introduction

In recent years, in the wave of deepening regional economic integration, economic and trade cooperation between China and ASEAN countries has ushered in a period of multiple strategic opportunities. With the official entry into force of the *Regional Comprehensive Economic Partnership* Agreement in 2022. It has greatly reduced tariff barriers, simplified and standardized non-tariff barriers, and significantly improved the level of trade facilitation. Superimposed on the "Belt and Road" initiative and the promotion of China's high-quality agricultural development strategy, China's agricultural export trade to ASEAN has entered a new stage of improving quality and efficiency. According to the information released by the General Administration of Customs, ASEAN has maintained the position of China's largest trading partner for agricultural products for eight consecutive years. In 2022, the total trade in agricultural products between China and ASEAN countries was 57.51 billion US dollars, accounting for 18.1% of the total trade in agricultural products. Among them,

exports amounted to 22.78 billion US dollars, accounting for 22.1% of total agricultural exports.

However, while the scale of trade continues to expand, green trade barriers are gradually becoming a major obstacle to restricting Chinese agricultural products from entering the ASEAN market. To protect the local agricultural industry and improve the level of food safety. In recent years, ASEAN-10 countries have followed the example of Western developed countries and continuously improved the environmental protection standards of imported agricultural products, the limits of pesticide residues, and the environmental protection requirements of packaging materials. According to statistics, since the establishment of the ASEAN Free Trade Area between China and ASEAN, the industries that have encountered the most TBT and SPS notifications in China's export trade to ASEAN are agriculture and food technology. This paper uses the stochastic frontier gravity model and the trade inefficiency model to study the impact, trade efficiency, and trade potential of green trade barriers on China's agricultural exports to ASEAN and to make suggestions for the export of China's agricultural products.

2. Literature review

Green trade barriers refer to a series of regulations and standards established by a country for imported products in the name of protecting the environment and human health. In recent years, as global environmental problems become more serious, coupled with the gradual rise of trade protectionism with non-tariff barriers as the core. Some countries have begun to protect their industries by setting up green trade barriers by formulating environmental standards, implementing environmental labels, and implementing health and quarantine systems. The phenomenon has also had an important impact on international trade [1]. In order to deeply explore the impact of green trade barriers, many scholars use a variety of methods to measure and analyze them. Zhao *et al.* [2] believed that green trade barriers are closely related to environmental protection requirements and standards. The investment in pollution control is an important manifestation of it, so they use the logarithm of the total expenditure on pollution emission reduction to quantify the degree of green trade barriers in various regions; Fang *et al.* [3] and Sun *et al.* [4] used the total number of quarterly notifications of technical trade barriers (TBT) related to agricultural products and health and phytosanitary measures (SPS) submitted by various countries to the World Trade Organization as indicators to measure the strength of the barriers. The more notifications, the stronger the barrier; Sun *et al.* [5] regarded green trade barriers as virtual variables. The value before implementation is 0, and the value after implementation is 1; Feng *et al.* [6] and Chen *et al.* [7] directly quantified the severity of green trade barriers through the pesticide residue limit standard. Diversified measurement methods reflect the complexity of green trade barriers themselves, and also provide analytical tools from different perspectives for subsequent research.

In the field of international trade research, the impact of green trade barriers on exports is an important issue that scholars are concerned about. Scholars at home and abroad have launched a multi-dimensional discussion on its influence direction and mechanism. In terms of positive impact, Fabrici *et al.* [8] revealed that the strict environmental regulation system empowers the improvement of export competitiveness. The study also innovatively proposed that the coordinated allocation of market-based tools and technical support policies can promote environmental quality improvement and export scale growth, providing a theoretical basis for the policy formulation of green trade policies in developing countries; Based on China's industrial practice, Chen [1] pointed out that the external constraints formed by green trade barriers can force local enterprises to carry out a quality revolution and drive the iterative improvement of the green product standard system; Brandi and

Schwab [9] believed that trade restrictive clauses in environmental clauses will reduce the export of pollution-intensive products in developing countries and reshape their trade structure. In terms of negative impact, Sun *et al.* [5] empirically found that green trade barriers have inhibited the scale of China's agricultural exports to the United States, Japan, and Europe to a certain extent. Wang [10] focused on regional industrial samples and argues that green trade barriers not only lead to a slowdown in export growth, but also weaken the competitiveness of products in the international market. Li [11] cut in from the perspective of mechanism analysis to explain that green trade barriers have an inhibitory effect on the export trade of agricultural products through the three dimensions of technical barriers, standard barriers, and information asymmetry. Gong [12] introduced the time dimension and used the dynamic GMM method of expanding the gravity model to carry out research. He found that green trade barriers formed an increasing and restraining trend on China's agricultural exports in the current and lag phases, and in the second phase, it turned to have a positive promotion effect on exports. This dynamic evolutionary characteristic provides a new analytical framework for understanding the long-term impact of green trade barriers.

Based on the above literature review, this article takes the impact of green trade barriers on China's agricultural exports to ASEAN as the starting point, and analyzes the characteristics of China's agricultural exports to ASEAN and the current situation of encountering green trade barriers; In combination with the green trade barriers and the actual situation of ASEAN-10 countries, introduce the relevant indicators of green trade barriers. Use the stochastic frontier gravity model and select the time-varying model, and empirically test the impact of green trade barriers with the help of Stata 18 measurement software; Measure the trade efficiency and trade potential of China's agricultural exports to ASEAN. The innovative points of this article are: From the perspective of research, there is already a study on the export of agricultural products by green trade barriers, but there is less dynamic analysis of the ASEAN market. o make up for the gap in the research of dynamic panel models in ASEAN, this article focuses on the impact and potential release of green trade barriers on China's agricultural exports to ASEAN; In terms of data and methods, the panel data of 2005–2022 is used to cover the critical period of RCEP, Quantify green trade barriers with TBT/SPS, and analyze the impact mechanism in depth in combination with the trade inefficiency model.

3. Current situation of China's agricultural exports and green trade barriers implemented by ASEAN

3.1. Overall situation of China's agricultural exports to ASEAN member states

With the development of science and technology and economy, China's agriculture is transforming towards a green and sustainable direction. The quality, safety, and security capabilities of agricultural products are continuously improving. While ensuring domestic supply, China has also become an indispensable member of the international agricultural trade system. China and ASEAN member countries are increasingly close in trade and cooperation in the field of agricultural products. Some ASEAN member countries are rich in tropical agricultural products, while China has an advantage in the deep processing of agricultural products and the construction of market channels. Under bilateral trade, both sides have effectively promoted the efficient integration of agricultural resources, tailored to their respective market demands, and more powerfully promoted the overall progress of regional agriculture. The trend of China's agricultural exports to ASEAN member countries is shown in **Figure 1**.

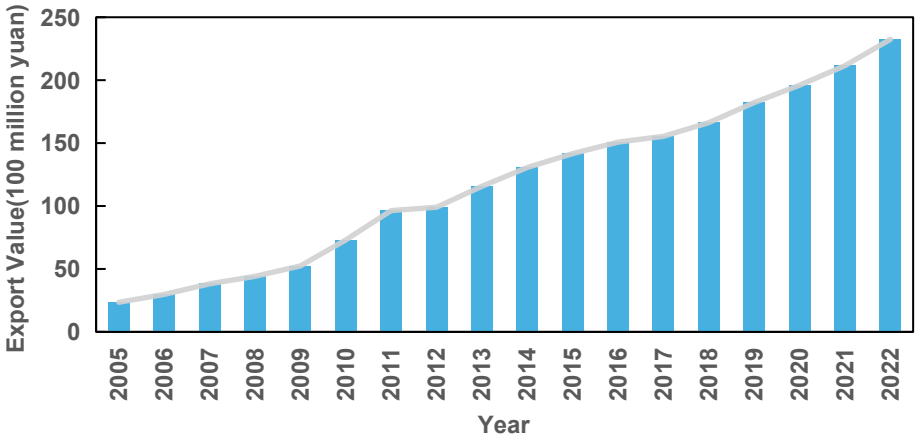

Figure 1. China's agricultural export trade volume with ASEAN member states, 2005–2022

It can be seen from the figure that from 2005 to 2022, China's agricultural exports to ASEAN member countries showed a continuous and stable growth trend. This trend reflects the deepening of bilateral agricultural trade cooperation between China and ASEAN, and reflects the gradual increase in the share of Chinese agricultural products in the ASEAN market. The two sides have formed a stable pattern of coordinated development in the field of agricultural trade, and the docking of market demand and trade links have become more and more stable; At the same time, it also shows that with the steady improvement of the quality of China's agricultural products and the continuous expansion of production, the import dependence of ASEAN countries on Chinese agricultural products is gradually increasing.

3.2. China's agricultural exports affected by green trade barriers

3.2.1. TBT and SPS notifications issued by ASEAN member states

TBT notification refers to the notification mechanism of the World Trade Organization (WTO) Technical Barriers Agreement (TBT Agreement). The scope of the notification covers many fields, including but not limited to food technology, chemical technology, environmental protection, health care and safety, agriculture, and household. This article selects agriculture (ISC classification 65) and food technology (ISC classification 67), which have an impact on the production, sales, and import and export of agricultural products.

SPS notification refers to the notification mechanism of the World Trade Organization (WTO) Agreement on Animal and Plant Hygiene Measures (SPS Agreement), which aims to protect food safety and animal and plant health. It includes three categories: food safety, animal hygiene, and plant hygiene measures. In order to make a specific analysis of the notification volume of TBT and SPS respectively, this article selects the situation of TBT and SPS notification in China's agricultural exports to ASEAN countries from 2005 to 2022. The details are shown in **Figure 2**.

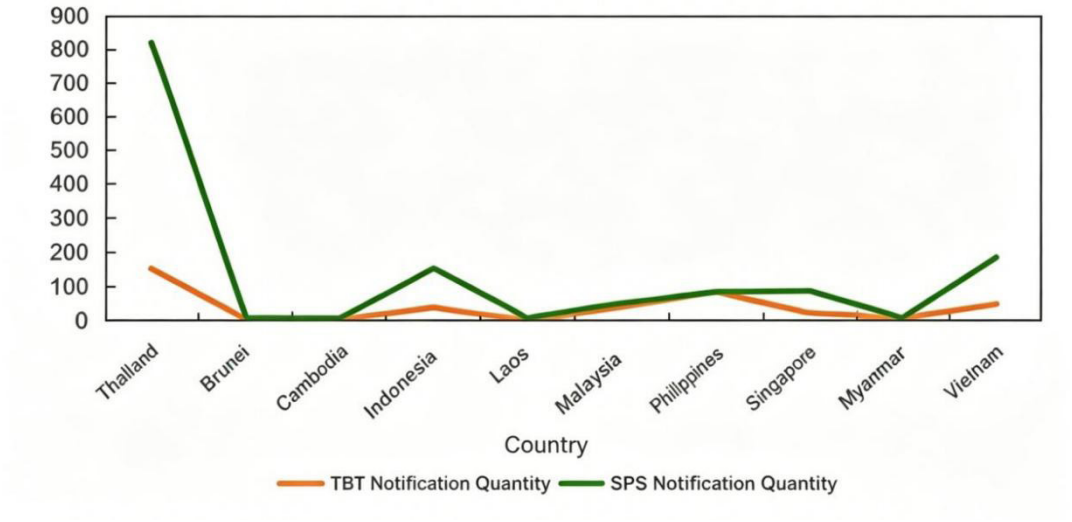

Figure 2. TBT/SPS measures encountered by China's agricultural exports to ASEAN, 2005–2022

Thailand, Indonesia, and the Philippines are at the forefront of the number of notifications, indicating that these countries have stricter technical measures on the import of agricultural products. For example, Indonesia has introduced a number of policies to restrict the export of Chinese fruits and vegetables, raise testing standards and increase enterprise costs. Brunei, Cambodia, Laos, and other countries have reported less often, which reflects that these countries are relatively lax in terms of technical measures for the import of agricultural products. It provides a more favorable market environment for China's agricultural exports.

In terms of the type of notification, SPS notification fluctuates significantly in Thailand, Vietnam, and other countries, while TBT notification is generally flat. It shows that the safety requirements of ASEAN countries for agricultural products such as hygiene and animal and plant quarantine are key factors affecting China's exports. China's TBT and SPS circular on ASEAN export agricultural products. Due to significant differences between countries, it is necessary to study the rules of each country in a targeted manner. In particular, focus on the SPS measures of Thailand and other "large households" to help agricultural products break through trade barriers and stabilize the ASEAN market.

3.2.2. Impact mechanisms and challenges of green trade barriers

From the current situation of China's agricultural exports and ASEAN's implementation of green trade barriers, it can be concluded that frequent and increasingly strict TBT/SPS notifications pose multiple challenges to ASEAN for China's agricultural exports. Compliance costs increase, and enterprises need to constantly adapt to new standards and invest in testing, certification, technical transformation and other expenses; The customs clearance time is extended, and the more complex inspection and quarantine procedures increase the risk of goods being delayed; Market access is blocked, and products that do not meet the new regulations may be detained, returned or even destroyed, directly losing market opportunities; Weak price competitiveness, the increased cost may eventually be passed on to product prices, weakening the competitive advantage of China's agricultural products.

4. Research methods and data sources

4.1. Model specification

This study uses the time-varying stochastic frontier gravity model to quantify trade potential and efficiency loss. It can capture how this efficiency evolves dynamically over time and identify the driving factors of efficiency loss through the trade inefficiency model. The specific form of the stochastic frontier gravity model is:

$$T_{ijt}=f(X_{ijt},\beta)\exp(v_{ijt}-u_{ijt}) \tag{1}$$

Among them, T_{ijt} represents the export trade of agricultural products, $f(X_{ijt},\beta)$ represents the stochastic frontier production function, β represents the unknown parameters, and v_{ijt} and u_{ijt} are independent of each other. The former is a random error term, and $v_{ijt} \sim N(0,\sigma_v^2)$, and the latter represents the trade inefficiency term.

When the trade inefficiency term is 0, that is, $u_{ijt}=0$, it means that it is the optimal trade state at this time, and the trade potential reaches the maximum value at this time. At this time, T_{ijt}^* represents the trade potential, namely:

$$T_{ijt}^*=f(X_{ijt},\beta)\exp(v_{ijt}) \tag{2}$$

Trade efficiency is the ratio of actual trade volume to trade potential, with a value of (0, 1). When there are no trade inefficiencies, this ratio is 1, meaning that trade efficiency is highest when no other factors interfere with trade.

$$TE_{ijt}=\frac{T_{ijt}}{T_{ijt}^*}=\exp(-u_{ijt}) \tag{3}$$

To account for the dynamic changes in the export trade efficiency of agricultural products, a time factor is incorporated into u_{ijt}, thereby transforming it into a time-varying model—specifically:

$$u_{ijt}=\left\{\exp\left[-\eta\left(t-T\right)\right]\right\}u_{ijt} \tag{4}$$

Where, $u_{it} \sim N^{+}(\mu,\ \sigma_u^2)$, η is the parameter to be estimated, when $\eta=0$, u_{ijt} does not vary with time; in this case, it is a time-invariant model. When $\eta>0$, trade inefficiency decreases as time increases. When $\eta<0$, the trade inefficiency term increases over time. The latter two cases represent time-varying models.

Substituting the trade inefficiency term u_{ijt} into the stochastic frontier gravity model yields the trade inefficiency model:

$$u_{ijt}=\delta z_{ijt}+\omega_{ijt} \tag{5}$$

Here, δ represents the parameters to be estimated for the factors influencing trade inefficiency; z_{ijt} denotes the exogenous variables affecting the dependent variable; and ω_{ijt} is the stochastic error term.

4.2. Model design and variable description

4.2.1. Construction of the time-varying stochastic frontier gravity model

Select variables such as the gross domestic product of ASEAN countries, the number of TBT/SPS notifications, the average annual exchange rate of currency, and the proportion of agricultural added value, and obtain the model calculation formula:

$$\ln(Export_{it})=\beta_0+\beta_1(TBT\_SPS_{it})+\beta_2\ln(GDP_{it})+\beta_3\ln(Agri_{it})$$
$$+\beta_4(ExchangeRate_{it})+\beta_5(FTA_{it})+\theta\ln(Export_{i,t-1})+(v_{it}-u_{it}) \tag{6}$$

When $u_{it}=0$, no additional resistance factors exist in agricultural export trade; at this point, the value of China's agricultural exports to country i reaches its maximum level, specifically, this value represents the trade potential. That is:

$$\text{Potential}_{it}=\beta_0+\beta_1(\text{TBT\_SPS}_{it})+\beta_2\ln(\text{GDP}_{it})+\beta_3\ln(\text{Agri}_{it})+\beta_4(\text{ExchangeRate}_{it})$$
$$+\beta_5(\text{FTA}_{it})+\theta\ln(\text{Export}_{i,t-1})+v_{it} \quad (7)$$

The dependent variable $Export_{it}$ refers to the value of China's agricultural exports (HS Chapters 01–24) to ASEAN country i in year t; The core explanatory variable TBT_SPS_{it} refers to the number of TBT/SPS notifications implemented by ASEAN country i in year t. The control variable GDP_{it} refers to the total GDP of ASEAN country i in year t. $Agri_{it}$ refers to the share of agricultural value added in ASEAN country i in year t. $ExchangeRate_{it}$ refers to the annual average exchange rate of the RMB against the currency of Country i. FTA_{it} refers to the Free Trade Agreement (FTA) dummy variable (equal to 1 after the entry into force of RCEP, and 0 otherwise). The dynamic term $\ln(Export_{i,t-1})$ represents the export value lagged by one period. Random error term v_{it}.

4.2.2. Construction of the trade inefficiency model

Based on the actual situation of agricultural trade between China and ASEAN countries, this study incorporates a number of key explanatory variables that can have a significant impact on bilateral trade flows in the short term when constructing a trade inefficiency model. These key variables include: The number of TBT/SPS notifications, the proportion of Chinese agricultural product-producing enterprises obtaining green certification, and the logistics performance index of exporting countries. The expression is as follows:

$$u_{it}=\delta_0+\delta_1 TBT\_SPS_{it}+\delta_2 Green\_Cert_{it}+\delta_3 BioSafety_{it}+\omega_{it} \quad (8)$$

TBT_SPS_{it} refers to the number of TBT/SPS notifications implemented by ASEAN country i in year t. $Green\_Cert$ refers to the proportion of Chinese agricultural products that have obtained green certification. LPI_{it} denotes the Logistics Performance Index of country i; ω_{it} denotes the random error term.

4.3. Data sources

In order to ensure the reliability of empirical results, this paper processes the relevant data logarithmically before empirical analysis. For some countries (such as Brunei, etc.), the missing values of relevant data have been processed by interpolation. China's annual export value of HS01-24 agricultural products to ASEAN countries, the data comes from the UN Comtrade database; The intensity of green trade barriers is measured by the total number of TBT/SPS notifications of China's WTO/TBT-SPS Circular Consulting Network; The GDP data of ASEAN countries comes from the World Bank; The exchange rate data comes from the average annual exchange rate of IMF; The percentage of ASEAN agricultural added value to GDP and the virtual variable of the free trade agreement. Take 1 after the RCEP takes effect. The data comes from the China Free Trade Zone Service Network; The data on the proportion of green certification of China's agricultural products comes from the China Green Food Development Center; The logistics performance index of ASEAN countries comes from the World Bank. All variable measurement methods and data sources strictly match the needs of empirical analysis.

5. Empirical analysis

5.1. Analysis of the results of the stochastic frontier gravity model

This paper employs Stata 18 to incorporate the processed data into a stochastic frontier gravity model; the first column presents the time-invariant model, while the second column presents the time-varying model. Detailed results are provided in **Table 1**. The parameter η in the time-varying model is significantly positive at the 1% significance level, indicating that the time-varying model is more appropriate than the time-invariant model.

Table 1. Regression results of the stochastic frontier gravity model

	Time-invariant model		Time-varying model	
Variables	**Coefficient**	***t*-value**	**Coefficient**	***t*-value**
TBT_SPS	-0.142**	-2.33	-0.182***	-4.23
ln(GDP)	0.687***	8.08	0.742***	7.27
ln(Agri)	0.213***	6.66	0.311**	2.41
Exchangerate	0.105**	2.19	-0.0001***	-3.33
FTA	0.186***	4.43	0.126*	1.88
L.ln(Export)	0.435***	5.72	0.402***	4.62
η			0.021***	3.67
Log-likelihood Value	-153.835		-147.076	
LR	22.37		32.74	

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

The results show that China's exports of agricultural products to ASEAN are significantly affected by multiple factors. For every additional TBT/SPS notification of ASEAN-10 countries, China's agricultural exports fell significantly by about 18.2%, which shows the substantial hindering effect of trade barriers. For every 1% increase in the GDP of ASEAN-10 countries, China's agricultural exports will increase by 0.742%, reflecting the pulling effect of ASEAN countries on China's demand for agricultural products. For every 1% increase in the added value of ASEAN, China's agricultural exports increased by an average of 0.311%, reflecting the complementary role between China and the agriculture of ASEAN-10 countries. The entry into force of RCEP has increased China's agricultural exports to ASEAN by an average of about 12.6%, proving that the high-level agreement reduces trade costs and has a positive effect. For every 1% increase in exports in the previous period, the current exports increased by 0.402%, indicating the path-dependent characteristics of historical trade models, supply chain networks, and market inertia.

5.2. Analysis of the results of the trade inefficiency model

This paper employs a trade inefficiency model to analyze the impact of inefficiency factors on China's agricultural exports to ASEAN countries from 2005 to 2022. The regression results of the model are presented in **Table 2**.

Table 2. Regression results of the trade inefficiency model

Variables	**Coefficient**	***t*-value**
TBT_SPS	0.318***	3.637
Green_Cert	-1.427***	-6.096

LP	-0.356***	-5.711
σ2	0.396	-
γ	0.769***	18.76
Log-likelihood Value	162.35	
LR	41.28	

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

The results show that the coefficient of TBT/SPS notifications is significantly positive, and the trade inefficiency is significantly improved, which is the same as expected; The environmental certification coverage coefficient of ASEAN countries is significantly negative, causing trade inefficiency to decline as expected; The logistics performance index coefficient of ASEAN countries is negative, which reduces trade inefficiency, which is the same as expected.

5.3. Analysis of the estimation results of trade efficiency and trade potential

Trade efficiency is a relative concept that reflects the extent to which the actual trade volume realizes its trade potential under the endowment of established resources. To analyze the measurement of the import trade potential of ASEAN countries, take 2019 as an example, as shown in **Table 3**.

Table 3. Import trade potential

Country	Trade efficiency	Actual import trade volume (USD 100 million)	Trade potential (USD 100 million)	Ratio of trade potential to actual import trade volume (times)
Singapore	0.9456	12.06	13.30	1.02
Malaysia	0.8342	55.57	64.89	1.17
Brunei	0.7423	0.17	0.24	1.41
Vietnam	0.7464	85.91	108.75	1.27
Thailand	0.7253	104.43	131.31	1.26
Laos	0.8874	2.48	2.77	1.12
Cambodia	0.4876	3.51	7.86	2.24
Philippines	0.1645	30.66	169.67	5.53
Myanmar	0.2324	11.42	47.05	4.12
Indonesia	0.0234	83.02	837.74	10.09

The trade efficiency between China and ASEAN countries shows a cascade difference. Singapore's trade efficiency is the highest; the actual trade volume is close to the potential value, and the market is close to saturation; Malaysia, Vietnam, Thailand, and other medium-efficiency countries have systematic potential space; Inefficient countries have great potential. Indonesia's actual trade volume of $8.302 billion accounts for only 9.91% of the theoretical potential of 83.774 billion US dollars; Cambodia's trade volume can grow by 124%. Brunei and Laos show individual characteristics.

6. Research conclusion and policy recommendations

6.1. Research conclusion

The results show that: For every additional item of ASEAN green trade barriers (TBT/SPS notification),

China's agricultural exports decreased significantly by 18.2%; Trade efficiency is polarized. Singapore has reached saturation, while Indonesia and the Philippines have 5–10 times the potential. It is revealed that technical barriers suppress trade through the triple mechanism of cost, time limit, and access, but institutional coordination and infrastructure upgrading can effectively break the barrier.

6.2. Policy recommendations

At the government level, first of all, through the establishment of a professional risk assessment team and the use of advanced forecasting models, timely and accurate prediction and analysis of possible green trade barriers can be made. Secondly, establish a sound information collection and feedback mechanism. Collect relevant information about green trade barriers at home and abroad through multiple channels, including policy dynamics, technical standards, etc., and provide timely feedback to enterprises and relevant institutions. Encourage enterprises to actively participate in information collection and feedback, and improve self-prevention awareness.

At the national level, under the framework of RCEP, promote the mutual recognition of the standards of agricultural residue standards between China and Vietnam and China and Thailand, and implement "pre-clearance inspection" for high-credit enterprises to reduce the customs clearance time.

At the regional level, we will jointly build a cold chain logistics corridor in China, Laos and Thailand to meet the temperature control requirements of fresh SPS, and export low-residue planting technology to Indonesia and the Philippines. Through the trinity strategy of "certification-mutual recognition-infrastructure," the conversion rate of potential markets will be increased by 30%.

Disclosure statement

The author declares no conflict of interest.

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