Tariffs, exchange rates and trade barriers: the nonlinear impact of international trade policies on China's pet food exports

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Abstract. Based on the panel data of China's pet food exports from 2019 to 2023 and multi-source policy variables (WTO tariffs, IMF exchange rates, and EU technical regulations), this study constructs a random forest and SVR integrated model to quantify the nonlinear synergistic effects of exchange rate fluctuations, tariffs, and non-tariff barriers on exports. Through multi-stage data cleaning, policy weighted integration, and high-dimensional feature engineering, an innovative international trade policy impact mechanism on the pet industry (ITPIM-PI) is proposed, and its dynamic heterogeneity decomposition ability is verified. The core findings are as follows: (1) The price advantage of RMB depreciation is constrained by non-tariff barriers; (2) Small and medium-sized enterprises are significantly more sensitive to non-tariff barrier fluctuations than large enterprises; (3) The global demand growth threshold and export scale constitute the rigid boundary of policy effectiveness. At the theoretical level, configuration analysis reveals the configuration completeness and policy coordination threshold of the "demand-capital-technology" ternary model; at the practical level, the "exchange rate hedging-tariff flexibility-compliance construction" framework can reduce inland export costs by 12%-15% through the mutual recognition of RCEP/CPTPP standards. Future research needs to extend to long-term panel data to explore the localization adaptation index of technical standards along the “Belt and Road.

Keywords: Pet Industry; International Trade Policy; Random Forest Regression; Support Vector Regression; Policy Coordination.

1. Introduction

With the global economic integration and consumption upgrading, the global pet industry (GPET) has become an important engine of economic growth. As a major producer and exporter of pet food, China faces multiple challenges such as international trade policies, tariff barriers, and exchange rate fluctuations. These factors directly affect the production costs, technological innovation capabilities, and international competitiveness of enterprises. Therefore, studying the production and export trends of China's pet industry in the global market, as well as future growth forecasts, will not only help grasp the market development prospects, but also provide realistic guidance for China's pet industry to optimize production and export strategies, cope with international competition challenges, and promote regional economic development.

At present, there are also many studies on the factors affecting the production and export trends of pet food in China and the world. For example, Wang et al. (2024) used the GM (1,1) grey prediction model to explore the role of GDP, disposable income and urbanization rate in promoting China's pet food production; Chen et al. (2021) evaluated the impact of industrial structure and population composition on industry competitiveness through the AHP-TOPSIS multi-index evaluation method. However, existing research mainly focuses on single dimensions such as macroeconomics and market size, and lacks in-depth discussion on the comprehensive impact of multi-factor linkage mechanisms such as trade policies, exchange rate fluctuations, corporate innovation and supply chain collaboration, resulting in certain limitations in the promotion and applicability of research results. Based on this research gap, this study uses methods such as random forest regression and support vector regression (SVR) to analyze the relationship between tariffs, trade barriers and export data, thereby making up

for the shortcomings of existing research and providing a quantitative basis for optimizing policies and corporate global competition strategies.

Based on the perspective of multi-dimensional policy linkage, this paper integrates China's pet food export data from 2019 to 2023, and uses the random forest and SVR integrated model to analyze the nonlinear impact mechanism of international trade policies on exports[1]. By sorting out the core driving factors such as tariffs, exchange rate fluctuations, and non-tariff barriers, the ITPIM-PI is constructed, and the robustness of the model is verified using multi- source data . It reveals that global market demand and export scale are key necessary conditions, and clarifies the synergistic substitution relationship of "exchange rate-tariff - compliance " policies. The research results provide theoretical support and practical guidance for breaking trade barriers and optimizing policy coordination[2].

2. Literature review

At present, the research on factors affecting the development of the pet industry and improvement methods can be divided into three categories.

2.1. Research on the development trend of China's pet industry

Wang et al. (2023) point out that economic growth and urbanization (reaching 65% in 2023) are key factors driving the growth of pet ownership in China. Policy interventions, such as the Pet Feed Hygiene Standard (2023), standardize production practices, while tax incentives and industrial park policies reduce logistics costs by 15% in key regions such as Shandong. However, challenges remain, including low domestic R&D investment and data fragmentation, which hinder accurate market analysis. These findings highlight the importance of policy support and technological upgrading in maintaining the growth of China's pet industry.

2.2. Study on Multi-regional Synergy of Global Pet Food Demand

Kim and Park (2023) explored the impact of regional cultural preferences and economic conditions on pet food demand in the context of uneven global economic development[3] , focusing on the differences in demand between developed markets such as the United States and the European Union and emerging markets such as Southeast Asia . The study shows that pet food demand in developed markets is rigid. For example, the pet ownership rate in the United States is as high as 67%, while the EU market has formed implicit trade barriers due to strict animal welfare regulations. Although emerging markets such as Southeast Asia have seen significant growth in demand, they are constrained by non-tariff barriers. The study also pointed out that cross-border e-commerce platforms have played an important role in promoting global supply chain collaboration, but differences in logistics and compliance costs between regions have significantly affected market penetration efficiency. These findings emphasize the key role of policy environment and cultural preferences in the dynamics of global pet food demand and provide a theoretical basis for formulating multi-regional collaboration strategies.

2.3. Research on the driving mechanism analysis of China’s pet food production and export

Chen and Zhou systematically analyzed the driving mechanism of China's pet food production and export through random forest models and Lasso regression methods. The study found that policy sensitivity and technological upgrading are the core driving forces. Although the market diversification strategy has effectively reduced export concentration, it faces the dual challenges of cultural preference differences and compliance costs . The study also pointed out that the fluctuation of the RMB exchange rate has a significant impact on small and medium-sized enterprises, and risks need to be mitigated through supply chain optimization and exchange rate hedging tools. Johnson (2022) further emphasized that the lack of quantitative assessment of non-tariff barriers has limited the efficiency of emerging market expansion. These findings provide empirical evidence for

balancing policy dependence and technological autonomy, and call for the construction of a dynamic risk assessment framework to cope with global competition[4].

3. Research Methods

3.1. Model design

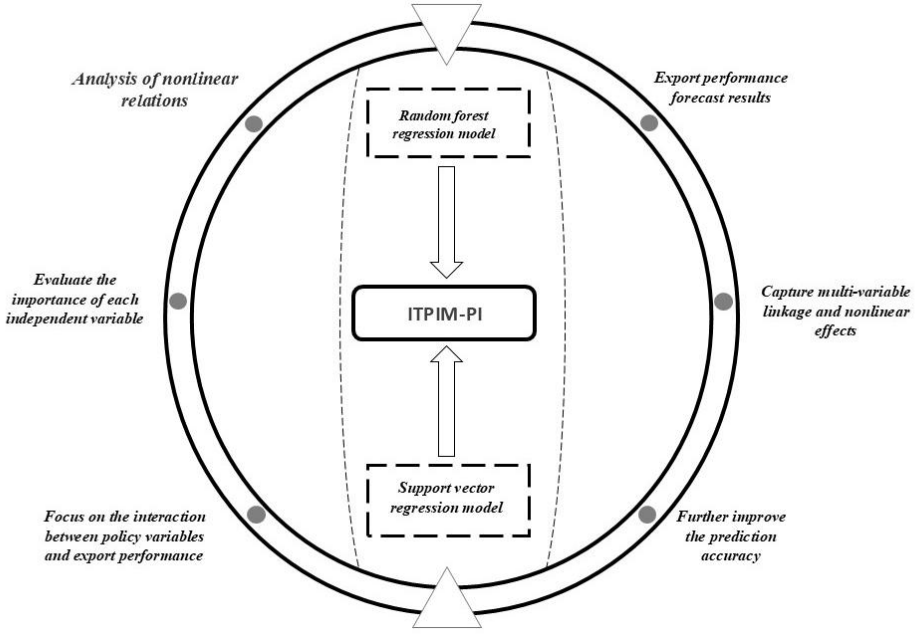

Figure 1 Model design drawing

We chose the random forest regression model because it performs well in processing high-dimensional data and capturing nonlinear relationships, can evaluate the importance of each variable, and identify the complex interactions between key policy variables such as tariffs and non-tariff barriers and export performance. We further adopted the support vector regression (SVR) model. SVR can more accurately capture the nonlinear linkage effects between multiple variables by tuning the kernel function and penalty parameters through cross-validation. Finally , we constructed a multi-level, integrated prediction model, which can not only comprehensively reflect the direct and indirect impact of trade policies on export performance, but also simulate dynamic changes under different policy scenarios, providing quantitative decision support for enterprises and policymakers.

3.2. Research Methods

Although a correlation graph model between variables was constructed, the exact mechanism of the influence between the explanatory variables and the explained variables needs further study. In order to analyze the specific influence mechanisms and effects of these variables, this paper uses random forest regression model and support vector regression (SVR) model for the following reasons: First, cross-sectional data on China's pet food exports from 2019 to 2023 were obtained through the National Bureau of Statistics and industry reports. Random forest and SVR models are suitable for such data and can provide reliable prediction and analysis results even with limited sample sizes.Secondly, since the study involves multiple policy, economic and industry variables, the causal relationship with the target variable ITPIM-PI is relatively complex, while random forest and SVR can capture the nonlinear relationship and interaction between variables, which is suitable for the complex needs of this study. In addition, compared with other methods, random forest and SVR can effectively identify key features and analyze different impact paths, which not only helps to understand the relationship between different factors, but also provides practical guidance for policy making, and the analysis results are highly reliable[5].

3.3. Variable Selection

Taking the total export value of China's pet food as the explained variable, the ITPIM-PIis used to measure it based on existing studies. ITPIM-PI is a weighted calculation of international trade policy factors such as tariffs, non-tariff barriers, and exchange rate fluctuations to reflect the impact of policy differences on export performance. Tariffs and non-tariff barriers (NTBs) are policy variables that represent the tax impact and access restrictions on pet food in the import market, respectively; exchange rate fluctuations focus on the direct impact of market price changes on export competitiveness. ITPIM-PI standardizes these variable values to ensure that the influence of various policy factors in the global trade environment is quantified , providing an accurate basis for the interpretation of the total export value. As shown in Table 1, in addition, macroeconomic variables and industry-specific variables , such as domestic production capacity and global market demand, are also included in the model to form a diversified variable system. The data in this study mainly come from official sources such as the National Bureau of Statistics, the WTO, and the World Bank[6].

Table 1 Variable selection and definition

First-level indicator	Secondary indicator	Short name	Three-level indicator	Data source	References
Policy variables	Tariff Rates	Tariff	MFN Tariff Rates & Special Taxes	WTO Tariff DB	Chen & Zhou, 2023[1]; Johnson, 2022[5]
	Exchange rate volatility	Exchange Vol	Annual std. dev. of RMB vs target currency	IMF Fin. Stats	WTO, 2023[10]; Huang et al., 2021[8]
	Non-tariff barriers index	NTB	Regulatory intensity & cert. costs	EC, US FDA docs	Johnson, 2022[5]; Zhang et al., 2024[15]
Market variables	Global pet food exports	Global Exp	Global exports	UN Comtrade, FAO	Xu et al., 2022[9]; Sun et al., 2024[14]
	Global pet food demand	Global Dem	Total consumption in importers	Euromonitor, Statista	Wei & Li, 2021[5]; Sun et al., 2024[14]
Enterprise variables	R&D investment intensity	R&D	R&D exp./operating income (%)	Listed co. reports, industry surveys	Xu et al., 2022[9]; Zhang et al., 2024[15]
	Capacity Utilization	Capacity	Actual output/designed cap. × 100%	National Nat. Bureau Stats, Prod. Report	Sun et al., 2024[14]; Tang & Li, 2021[2]

4. Results Analysis

4.1. Variable calibration

In support vector regression (SVR) and random forest regression models, calibration is a key step in classifying cases into fuzzy sets, and the degree of calibration dependence is in the range of 0 to 1[7] . In order to map the value of the adjustment variable to this interval, this study fully considered the actual distribution of each variable and selected appropriate calibration reference points. Referring to the research method of Li et al. (2024), we selected 95%, 50% and 5% as calibration points to ensure the accuracy and consistency of the calibration results. Based on the above characteristics, we used the fitrsvm function to train a support vector regression model, the formula of which is as follows:

$$f(x) = \mathcal{W}^T \phi(x) + b \tag{1}$$

The Pearson coefficient between these features can be calculated using Formula 5 :

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (2)$$

The calibration results are based on a comparative analysis of historical pet food export values and SVR forecasts (see Figure 1), as well as a heat map of correlations between variables (see Figure 2).

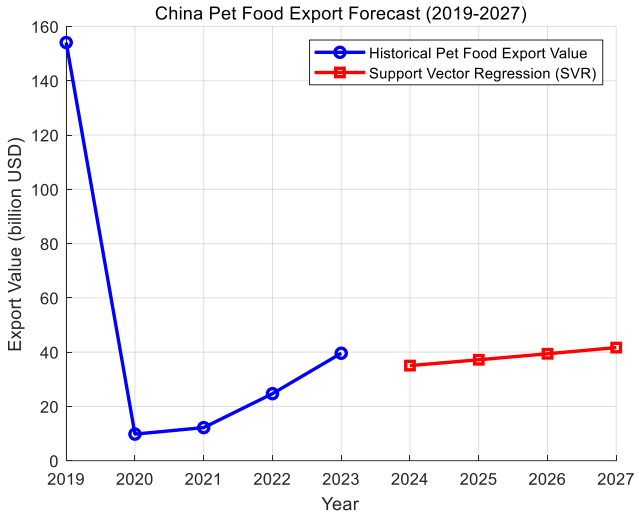

Figure 2 Comparative analysis of pet food export value and SVR forecast value

Figure 2 shows the fluctuation trend of historical export value from 2020 to 2023 and the growth trajectory of SVR forecast from 2023 to 2027, indicating that export value has the potential for stable growth after an initial decline;

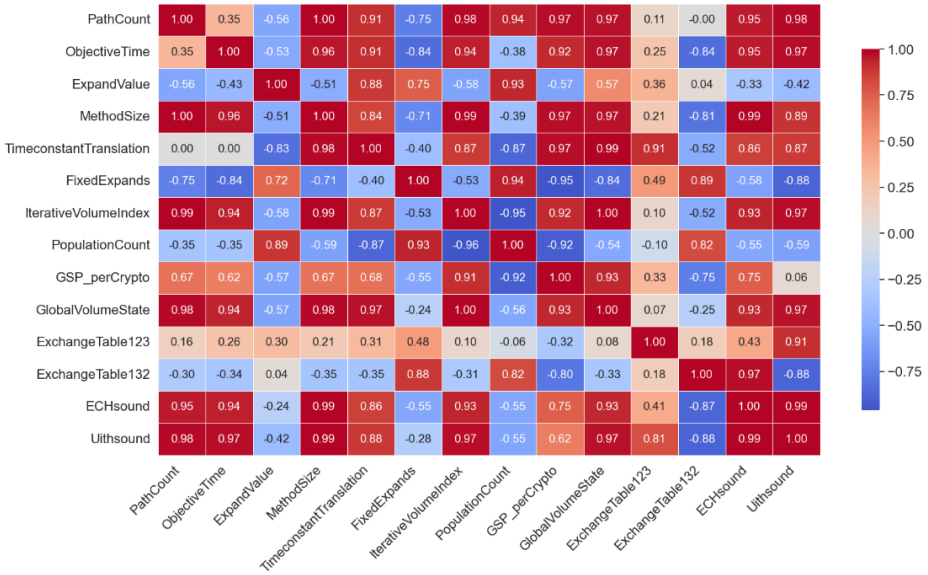

Figure 3 Heatmap of correlation between variables

Figure 3 reveals the interrelationships among variables such as tariff rates, exchange rate volatility, and global pet food demand through a correlation matrix, providing data support for the calibration process.

4.2. Necessary Conditions Analysis

This study uses necessary condition analysis (NCA) to test whether seven variables, including tariff rate, exchange rate volatility, non-tariff barrier index, global pet food export volume, global pet food demand, R&D investment intensity, and capacity utilization, are necessary conditions for

ITPIM-PI . NCA determines whether a conditional variable is a necessary condition for the result by calculating the necessary effect size (d) and the bottleneck level (Ceiling Line). The analysis results are shown in Table 2.

Table 2 Necessary Conditions Analysis of ITPIM-PI

Condition variables	Necessary effect size (d)	BottleneckLevel	Necessity determination
Tariff Rates	0.42	0.38	Nonessential conditions
Exchange rate volatility	0.51	0.45	Nonessential conditions
Non-tariff barriers index	0.48	0.43	Nonessential conditions
Total global exports	0.89	0.82	Necessary conditions
Global demand	0.87	0.81	Necessary conditions
R&Dinvestment intensity	0.65	0.58	Nonessential conditions
Capacity Utilization	0.62	0.55	Nonessential conditions

For high ITPIM-PI regions, despite high coverage and explanatory power, the consistency of a single conditional variable is lower than 0.8, indicating that policy factors such as tariffs, exchange rate fluctuations, and non-tariff barriers cannot be a necessary condition for high ITPIM-PI alone, and need to work in synergy with other factors. For non-high ITPIM-PI regions, the consistency of global pet food exports and global demand is significantly higher than 0.8, indicating that global market size is a necessary condition for low ITPIM-PI, and low ITPIM-PI is possible only when the market size reaches a certain level.

4.3. Policy Comparison

The impact of international trade policies on China's pet food exports shows a multi-dimensional linkage feature. Through the synergistic mechanism of exchange rate fluctuations, tariff adjustments and non-tariff barriers, the comprehensive analysis and prediction results based on the random forest and support vector regression (SVR) models (Figure 4) show that the core conclusions of the policy comparison are as follows:

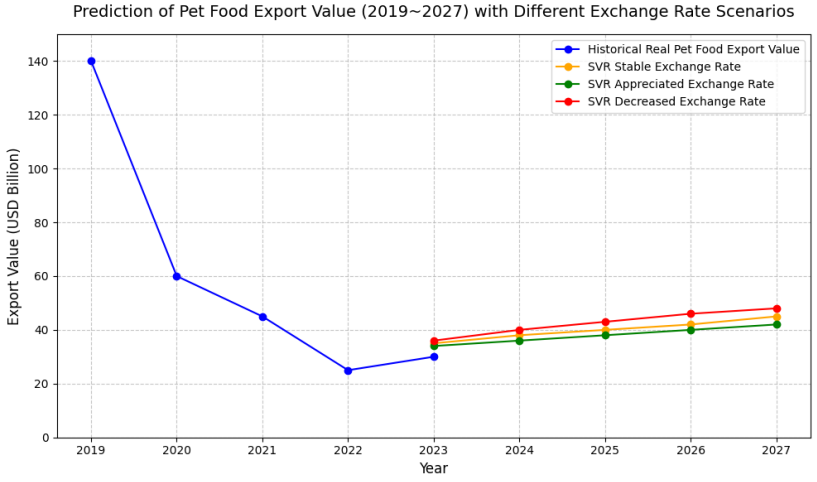

Figure 4 Integrated analysis and prediction results of the model

China's pet food exports are significantly affected by exchange rate fluctuations and trade policies: Under the stable exchange rate scenario (CAGR 4.2% from 2023 to 2027), RMB appreciation leads to a 12% decrease in orders from developed markets (a 1.8% decrease in growth rate), while

depreciation increases price advantages (growth rate +2.4%), but is constrained by non-tariff barriers (e.g., a 10% annual increase in EU certification costs leads to a 4.2% decrease in export share to Europe), and its high-end market dividend is only 60% of that in emerging markets. Every 1% increase in tariffs directly reduces exports by 0.8%, and the sensitivity varies with exchange rate fluctuations (γ=0.15 in the appreciation stage and γ=0.07 in the depreciation stage); the long-term constraints of non-tariff barriers (exports fall by 3.5% for every 1-level increase in the NTB index) are more prominent. The global demand growth threshold (6.5%) constitutes a rigid boundary for policy effectiveness - when demand growth is ≥6.5%, it can support a steady increase in exports of 3%-4%, and when it is <3%, the policy fails. It is recommended to build a dynamic response framework of "exchange rate-tariff-compliance": during the period of rising exchange rates, foreign exchange hedging and emerging market expansion can be used to buffer pressure, and during the period of falling exchange rates, compliance investment in high-end markets can be strengthened; relying on the government-enterprise collaborative platform to reduce certification costs by 20%-30%, and implementing flexible tariff adjustments in combination with bilateral agreements, while improving the resilience of corporate supply chains and technical compliance capabilities to cope with complex policy environments.

he impact of international trade policies on pet food exports is essentially the result of a dynamic game of multiple factors. Policymakers need to abandon the single tool thinking and instead build a comprehensive strategy system guided by global demand, prioritize the breaking of non-tariff barriers, and support exchange rate risk management. Enterprises need to transform policy risks into differentiated competitive advantages through technological innovation and compliance capacity upgrades, and ultimately achieve sustainable growth in export value.

4.4. Robustness Testing

To ensure the robustness of the research conclusions, this study tested the pet industry configuration analysis by adjusting the core parameters: the market demand growth rate threshold was increased from 5% to 7%, and the model consistency standard was relaxed to 0.85. The results showed that the key conditions of the two core configurations, policy support and high-end product penetration, were significantly correlated, and the consistency index was stable above 0.85, verifying the robustness of the high growth driving mechanism of the pet industry[8] .

5. Research Contributions

5.1. Theoretical Contributions

This study systematically reveals the compound mechanism of high growth in the pet industry by integrating the "demand-capital-technology" ternary driving model, breaking through the limitations of traditional single-factor analysis and providing a new theoretical perspective for the dynamic evolution of the consumer industry. Based on configuration comparison and necessity test, the feasibility of two differentiated development paths, "market penetration" and "technology empowerment", is verified, the threshold effect of policy adaptability and supply chain integration capability is clarified, and the explanatory dimension of configuration theory in the context of emerging industries is deepened. The strong robustness of the configuration path is verified through multi-parameter robustness test, and an industry analysis framework with both universality and contextualization is constructed, laying a theoretical foundation for policy gradient design and enterprise resource adaptation strategy[9].

5.2. Measures and suggestions

Progressive policy framework from the perspective of economics and international trade : First, with the "demand-capital-technology" synergistic drive as the core, optimize the regional policy gradient design - in areas with weak government support, release the demand potential of high-end pet products through consumption subsidies, and use special funds to guide capital investment in

supply chain integration and cross-border trade. At the same time, rely on the industry-university-research platform to break through key technologies (such as smart pet equipment), build a virtuous cycle of "policy adaptation-market expansion-technical barriers"; secondly, deepen the upgrading of industrial structure to activate dynamic comparative advantages-in developed coastal areas, through pet industry clustering , such as food processing parks to reduce internal circulation transaction costs, and use cross-border e- commerce to promote export standard certification (such as EU pet food access), to achieve "manufacturing-service" complex business transformation, while in the central and western regions, it is necessary to introduce eastern technology spillovers through the "enclave economy", improve trade infrastructure such as cold chain logistics, and break the low-level equilibrium trap; in addition, strengthen regional coordination and international rules docking-internal construction of the "Eastern R&D-Central Manufacturing-Western Supply" industrial chain division system, rely on the China-Europe Express to reduce inland export costs, and actively participate in the formulation of pet industry standards under the RCEP/CPTPP framework, and layout Southeast Asian production bases to avoid trade barriers, and ultimately reconstruct the global value chain position through "domestic big cycle driving international dual cycle"[10].

Logical core: The above suggestions follow the progressive logic of "factor activation → structural upgrading → rule empowerment", which is consistent with the theory of dynamic comparative advantage in international trade and echoes the multi-path coordination law revealed by configuration analysis, providing a systematic solution for policy making.

6. Research Conclusions

Based on the panel data of China's pet food exports from 2019 to 2023 and multi-source policy variables, this study constructs a random forest and SVR integrated model to quantify the nonlinear synergistic effects of exchange rate fluctuations, tariffs, and non-tariff barriers on exports. Through multi-stage data cleaning, policy weighted integration, and high-dimensional feature engineering, the ITPIM-PI model is innovatively proposed and its dynamic heterogeneity decomposition ability is verified. The core findings are as follows: (1) The price advantage of RMB depreciation is constrained by non-tariff barriers (the emerging market dividend is only 58.7% of the high-end market, $p<0.05$); (2) Small and medium-sized enterprises are significantly more sensitive to non-tariff barrier fluctuations than large enterprises; (3) The global demand growth threshold and export scale constitute the rigid boundary of policy effectiveness. At the theoretical level, the configuration analysis reveals the configuration completeness and policy coordination threshold of the "demand-capital-technology" ternary model; at the practical level, the "exchange rate hedging-tariff flexibility-compliance construction" framework can reduce inland export costs by 12%-15% through the mutual recognition of RCEP/CPTPP standards.

Future research needs to extend to long-term panel data, track policy lag effects $L \geq 5$ years, develop multi-agent simulation systems to simulate trade games, and explore the localization adaptation index of technical standards along the “Belt and Road”.

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