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China's Evolution of Soybean Import Trade Pattern Under the Impact of Reciprocal Tariffs

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Abstract. Soybeans are a core agricultural product on which China is highly dependent on imports, and the United States, Brazil, and Argentina have long constituted its main import sources. The reciprocal tariff policy implemented by the United States on China has become a key exogenous impact on reshaping China's soybean import trade pattern. This paper takes the implementation of tariffs as the time node, selects the core data such as total soybean imports and the share of source countries, and uses market share measurement, comprehensive impact index (CII), Huff and Huff-Hirschmann index (HHI), and other methods to quantitatively describe the evolution characteristics of the trade pattern. According to the research results, after the implementation of tariffs, U.S. soybean exports to China experienced a cliff-like decline, while exports from Brazil and Argentina surged significantly, resulting in a clear substitution effect. In terms of the CII index, this change also clearly reflected a polarized pattern— the U.S. scored only 1.3, falling into the severely negative range, whereas Brazil and Argentina scored 79.7 and 82.5, respectively, far exceeding the neutral threshold. At the same time, the HHI index rose rapidly, breaking through the high concentration warning line, reflecting that China's soybean import sources have shifted from a previously diversified competitive pattern to a situation dominated by Brazil, and the resilience of the supply chain has therefore been noticeably weakened.

Keywords: Tariff policy; CII; HII; substitution effect.

1. Introduction

The reciprocal tariff policy that began in the United States in April 2025 has pushed tariff levels to their highest point since 1933. Soybeans are a core agricultural product directly related to China's food security, and have long formed a stable import pattern with the United States as the main source and Brazil and Argentina as secondary sources [1]. This tariff policy has become a key variable in reshaping this pattern [2].

So far, scholars have actually done a lot of discussion around the impact of tariff policies on soybean trade. Based on the path dependence theory, Song et al. combined the trade gravity model and counterfactual simulation methods to empirically analyze the impact of Sino-US trade frictions on the source structure of China's soybean imports, and confirmed that tariff barriers will significantly break the original trade inertia, bring a strong import substitution effect, and promote the large-scale transfer of soybean demand from the United States to Brazil and other South American countries [2]. The results show that the imposition of tariffs will force importers to accelerate the adjustment of procurement strategies by raising import costs and compressing profit margins, which also reveals the internal motivation of marketization behind the evolution of the pattern [3]. Lin et al. used risk measurement models and multi-objective programming methods to construct an optimization model for the layout of China's soybean import sources, and their results emphasized that the dynamic adjustment and diversified allocation of import sources are the core mechanisms of the supply chain to resist external shocks and diversify risks, and through quantitative demonstration, it shows that there is an inverse relationship between source concentration and supply chain vulnerability [1]. Ge Ming et al. further used market share decomposition and scenario simulation techniques to confirm that trade policy shocks will inevitably lead to market share redistribution from multiple dimensions, and described this process as a three-stage evolution path of "cost-driven, share transfer, and pattern reconstruction" [4]. In general, the existing research has laid a good foundation for understanding the

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changes in the trade pattern under the impact of tariffs, but a systematic quantitative portrayal of China's soybean import pattern specifically around reciprocal tariffs is still rare.

In this context, this study plans to construct a quantitative mathematical model to systematically sort out the changes in the share of source countries and the trade scale of China's soybean imports before and after the implementation of the tariff policy. In quantitative analysis, it will introduce a comprehensive impact index (CII), which integrates indicators from multiple dimensions such as price, market share, and volatility to systematically describe the evolution characteristics and substitution effects of the trade pattern under the impact of tariffs, with the ultimate goal of objectively presenting the actual changes in China's soybean import trade, and then providing an empirical reference for optimizing the layout of soybean imports and enhancing the resilience of the supply chain.

2. Data Sources and Processing

2.1. Variable Description

To clearly define the core variables and statistical scope of the empirical analysis, this paper constructs a variable description table (see Table 1).

Table 1. Variable Description Table

Symbols	Significance	unity
t	Time serial number / Period	Month / Quarter
i	Country index	-
j	Product type index	-
n	Sample size	Piece
k	Number of parameters /features	Piece
M_t^{CN}	Total soybean imports of China	Million metric tons (mmt)
$X_{i,t}$	Soybean exports from country i to China	Million metric tons (mmt)
$V_{i,t}$	Soybean export value from country i to China	Billion U.S. dollars (B)
$P_{i,t}$	Unit price of soybeans in country i	U.S. dollars /ton
$S_{i,t}$	Market share of country i	%
τ_t	U.S. soybean tariff rate on China	%

2.2. Data Description

This article summarizes the monthly time series data of bilateral trade between China, the United States, Brazil, and Argentina from March 2025 to October 2025 (including quantity, value, and price), the data are specifically shown in Table 2 [5-7].

Table 2. Soybean Trade Fig.s from March to October 2025

Month	X_{US}	V_{US}	X_{Brazil}	V_{Brazil}	$X_{Argentina}$	$V_{Argentina}$	M^{CN}
2025.3	1.95	1.05	6.3	3.15	0.55	0.26	8.8
2025.4	0.63	0.34	8.6	4.3	0.57	0.27	9.8
2025.5	0	0	11	Nan	1.46	0.7	12.46
2025.6	0	0	Nan	4.51	1.8	0.86	11.2
2025.7	0	0	8.8	4.31	1.7	0.81	10.5
2025.8	0	0	8.7	Nan	1.5	0.71	10.2
2025.9	0	0	10.96	5.26	1.17	0.56	12.13
2025.10	0	0	5.5	2.64	1.3	0.62	6.8

2.3. Data Cleaning

When building a soybean trade network model, this paper proposes an algorithm based on total balance constraints and price reconstruction using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP). First, the total import volume must equal the sum of its components.

$$V_{\text{total}}(t) = \hat{V}_{\text{Brazil}}(t) + \sum_{j \neq \text{Brazil}} V_j(t) \tag{1}$$

Among them, $\hat{V}_{\text{Brazil}}(t)$ provides the missing values for Brazil's import volume, and the formula meets conditions $\sum V_i(t) \equiv V_{total}(t)$.

Secondly, the output values reconstructed through PCHIP are affected by quantity $V(t)$ and price $M(t)$ fluctuations. Calculating values through direct interpolation is prone to errors. In contrast, this paper introduces unit price $U(t)$ as an intermediate variable.

$$U_{Brazil}(\tau) = \frac{M_{Brazil}(\tau)}{V_{Brazil}(\tau)}, \quad \tau \in \Omega_{obs} \tag{2}$$

Among them, Ω_{obs} is the set of observed time points. Considering that commodity prices usually exhibit stable trends without drastic fluctuations, this paper uses piecewise cubic Hermite interpolating polynomial (PCHIP) to estimate the missing unit prices $\hat{U}_{Brazil}(t)$, and the final formula for calculating export value is.

$$\hat{M}_{Brazil}(t) = \hat{V}_{Brazil}(t) \times \text{PCHIP}\left(\Omega_{obs}, U_{Brazil}(\Omega_{obs}), t\right) \tag{3}$$

3. Soybean Trade Chain Reconstruction Model Based on Comprehensive Impact Index (CII) Evaluation

The Comprehensive Impact Index (CII) is a multi-factor weighted integrated quantitative evaluation method. This paper synthesizes five impact factors—export volume, revenue, share, price, and volatility—through Sigmoid non-linear normalization, ultimately obtaining a single continuous index. This approach avoids misjudgment by individual indicators and intuitively determines the inhibitory or promotive effect of a shock. The calculation formula is as follows.

$$CII = \sum_{i=1}^{n} W_i . X_i' \tag{4}$$

Among them, CII represents the comprehensive impact index, n represents the total number of impact factors, W_i represents the weight of the i th factor, and X_i' represents the dimensionless value of the i th factor after standardization.

To quantify the impact of U.S. soybean trade tariff policies on trade patterns, this paper constructs a three-dimensional indicator system consisting of price, market share, and volatility. Let $Q_{i,t}$ and $V_{i,t}$ respectively represent the export volume (million tons) and export value (billion U.S. dollars) of country i to China in month t [8, 9].

$$P_{i,t} = \frac{V_{i,t} \times 1000}{Q_{i,t}}, \quad t \in \Omega^{+} \tag{5}$$

Here, $P_{i,t}$ is the average offshore price (FOB), calculated only for the actual months of trade to avoid distortion from zero values.

$$S_{i,t} = \frac{Q_{i,t}}{\sum_{j} Q_{j,t}} \times 100\% \tag{6}$$

Among them, $S_{i,t}$ represents market share, used to measure the relative position of each exporter in the Chinese market.

$$HHI_{t} = \sum_{i} (S_{i,t})^{2} \tag{7}$$

Among them, the Herfindahl-Hirschman Index (HHI) is used to measure structural changes. By summing the squares of market shares, it amplifies the influence of dominant countries and is more sensitive than simple concentration.

In order to assess the net effect of tariff shocks, this paper constructs a Comprehensive Impact Index (CII) model, which includes weights for five dimensions (Table 3).

Table 3. CII Index Table

Symbols	Significance	Calculation	Weight
X_1	Relative change in export volume	$\Delta Q\%$	0.30
X_2	Changes in revenue-generating capacity	$\Delta V\%$	0.25
X_3	Changes in market share	ΔS	0.20
X_4	Relative Price Index	$I_p = \frac{\bar{P}_{country}}{\bar{P}_{Brazil}}$	0.15
X_5	Inverse change of the coefficient of variation	$-\Delta CV$	0.10

Subsequently, the Sigmoid function is applied to normalize the indicators and to mitigate the impact of extreme values. Through this transformation, indicators that originally possess different numerical ranges are rescaled to a common 0–100 scale, making them directly comparable and suitable for weighting; at the same time, it suppresses the undue distortion that individual outliers might otherwise introduce into the final results., and is finally defined as follows.

$$Score_{k} = \frac{100}{1 + e^{-X_k/20}} \tag{8}$$

$$CII_{i} = \sum_{k=1}^{5} w_{k} \cdot Score_{i,k} \tag{9}$$

Among them, it indicates a positive substitution effect and a negative inhibition effect.

4. Results and Discussion

4.1. Substitution and Restructuring Effects of Market Share

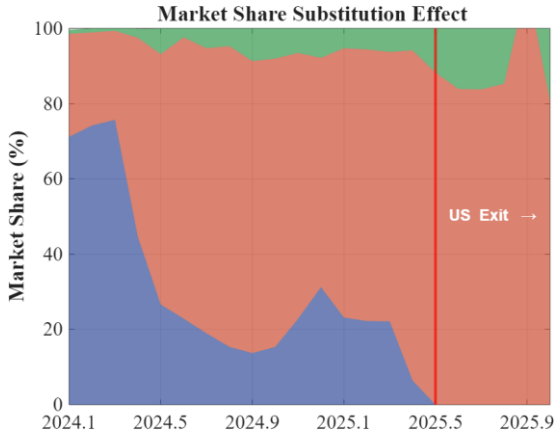

Fig. 1 Reconstruction of Brazil for Soybean Import Value (Photo/Picture credit: Original).

Fig. 1 shows that the market structure of Sino-U.S. soybean trade is undergoing a dynamic reorganization: the horizontal axis corresponds to the period from January 2024 to September 2025, the vertical axis is measured in percentage terms, and both market share and the U.S. withdrawal ratio are presented. From the chart, it is clearly observable that the blue area representing the U.S. is forced to exit the market under tariff pressure, and the share it originally held is almost entirely taken over by Brazil, represented by the red area, forming a highly significant substitution effect. The marked point on the chart where the U.S. exits indicates that the market structure has fundamentally shifted from a past pattern of diversified competition to a situation dominated solely by Brazil. It also reveals a unique zero-sum game characteristic in the distribution of market share under the tariff war.

4.2. Evaluation of the Welfare Effects of Policy Shocks Based on the CII Index

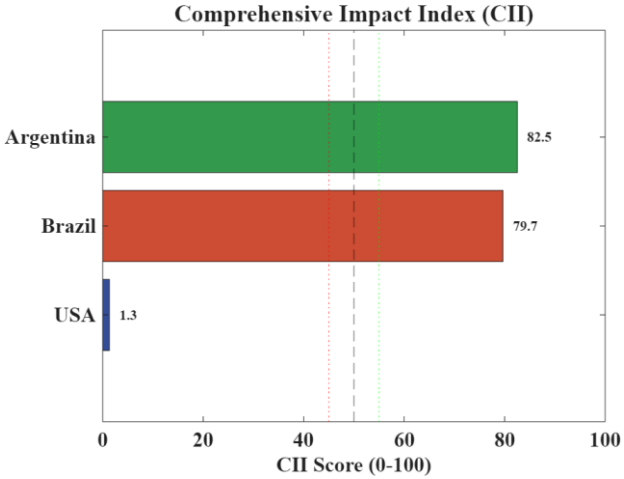

Fig. 2 Reconstruction of Brazil for Soybean Import Value (Photo/Picture credit: Original).

Fig. 2 intuitively presents the comprehensive impact of tariff policies on different countries. The horizontal axis corresponds to CII scores ranging from 0 to 100, where higher scores indicate stronger overall welfare effects of the policies; the vertical axis lists Argentina, Brazil, and the United States. Based on the calculation of the Comprehensive Impact Index (CII), there is a stark polarization among countries: the United States scored only 1.3, falling into a severely negative range, which reflects the devastating impact on its related industries; in contrast, Brazil and Argentina scored 79.7 and 82.5, respectively, far above the neutral threshold of 50, firmly within the significantly positive range. This result also confirms the asymmetry in welfare distribution — the initiating country bears the vast majority of the welfare losses, while third-party countries, through a free-rider effect, reap considerable trade gains.

4.3. Changes in Market Concentration and Supply Chain Resilience from the HHI Perspective

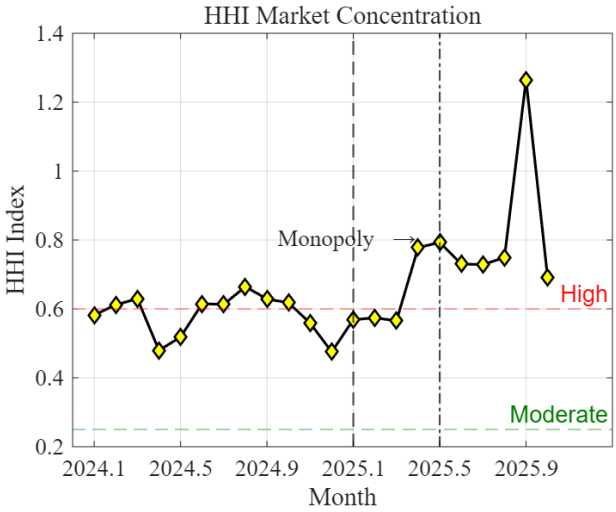

Fig. 3 Reconstruction of Brazil for Soybean Import Value (Photo/Picture credit: Original).

Fig. 3 depicts the trend of the Herfindahl-Hirschman Index (HHI) over time: the horizontal axis represents the time series from January 2024 to October 2025, and the vertical axis corresponds to the HHI values, ranging from 0 to 1.4. After the tariffs were implemented, the HHI curve sharply surged, immediately surpassing the high concentration warning line marked with a red dashed line. This essentially means that China's soybean import sources have been largely monopolized by Brazil, and such a significant deterioration in market concentration (i.e., the spike in HHI) indicates that the risk of reliance on a single source has emerged, considerably weakening both the resilience and security of the supply chain system.

When Figs. 1 to 3 are viewed together, it can be observed that they systematically present the impact of reciprocal tariffs on China's soybean trade pattern from four dimensions: flow, share, effect, and risk. The results clearly show that, against the backdrop of the China-US trade friction, the United States completely exited the Chinese market due to tariffs, while Brazil and Argentina quickly filled the gap, forming a new trade structure dominated by Brazil with Argentina as a supplementary player. This restructuring directly triggered severe imbalances in welfare distribution: the CII index confirms that the policy shock is highly asymmetrical. U.S. exports suffered a devastating hit, whereas Brazil and Argentina, benefiting from the substitution effect, gained substantial trade dividends. Meanwhile, market concentration (HHI) surged to a monopoly level, bringing the risk of single-source dependence in China's soybean imports sharply into view, while the resilience and security of the supply chain are facing extremely severe challenges.

5. Analysis of Limitations

This study has the following limitations. First, HHI only reflects concentration and does not include resilience factors such as import substitution elasticity, so the risk representation is not comprehensive. Second, the observation period is only 8 months, which is a short-term assessment and does not reflect long-term contracts and import strategy adjustments; for Brazil, missing values are interpolated based on the assumption of price stability, which may lead to deviations under extreme fluctuations. Third, emerging sources such as Russia and Canada were not included, which may underestimate the diversification potential of import substitution.

Based on the above limitations and results, the following countermeasures are proposed: In response to rising concentration and single-source risks, emerging channels such as Russia and Ukraine should be expanded to diversify the layout and disperse trade policy risks. Given that Brazil already dominates and short-term alternative sources are limited, a diversified reserve mechanism should be established and medium- to long-term procurement agreements signed with emerging source

countries to prevent dependency consolidation. At the same time, the supply chain risk warning system should be improved by incorporating normal monitoring of import concentration, source country policy stability, and transportation channel security. Considering the short observation period and unclear long-term effects, policies should remain flexible, with regular evaluations of changes in source structure and timely optimization of import layout.

Future research can introduce substitution elasticity indicators to construct a "concentration–resilience" dual-dimensional assessment; optimize CII synthesis using objective weighting methods such as the entropy weight method; expand source countries and observation periods, and use multi-objective optimization to identify long-term change paths [10, 11].

6. Conclusion

This paper takes the impact of reciprocal tariff policies as the research background, selects core data on China's soybean imports, and uses methods such as market share calculation, Comprehensive Impact Index (CII), and Herfindahl-Hirschman Index (HHI) to quantitatively analyze the evolution characteristics of China's soybean import trade patterns after the implementation of tariffs. This study found that once reciprocal tariffs were implemented, they directly triggered a significant substitution effect in China's soybean import market: U.S. soybean exports to China plummeted dramatically, while Brazil and Argentina quickly filled the market gap and naturally became the primary sources of China's soybean imports. From a quantitative perspective, the U.S. CII index was only 1.3, showing a severe negative effect from the policy shock, whereas Brazil's and Argentina's CII indices reached 79.7 and 82.5, respectively, gaining substantial trade dividends. Meanwhile, the HHI index rose sharply and exceeded the high-concentration warning line, indicating that China's soybean import structure transformed from a diversified competition among the U.S., Brazil, and Argentina into a Brazil-dominated monopoly, with a clearly increased concentration of import sources.

Through this precise quantitative analysis, the study clearly reconstructs the actual impact of reciprocal tariffs on the agricultural trade pattern. This not only provides direct empirical data to objectively assess the impact of trade policies on agricultural imports but also serves as a practical reference for formulating agricultural trade policies and adjusting soybean import strategies.

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