

Original Paper

Quantitative Analysis of the Trade and Economic Effects of X Country's Reciprocal Tariff Policy Based on a Combined Forecasting Model

Jiali Du^{1,a,*}

¹ Business School, Xi'an International Studies University, Xi'an, China

^a 3204243702@qq.com

* Corresponding author

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Abstract

This paper systematically analyzes the heterogeneous impacts of X Country's reciprocal tariff measures on global trade patterns and regional economic operations by addressing five core research questions.

Firstly, based on the Rotterdam model, it quantitatively estimates the import demand elasticity of A Country's soybeans sourced from three major exporting countries against the backdrop of X Country's tariff adjustments, and employs the grey forecasting model to dynamically simulate and forecast the changing trends of soybean export volume and trade value under fluctuating tariff regimes.

Secondly, this study establishes a log-linear import demand function to empirically measure the market competitiveness of J Country's automobile manufacturers in the X Country's consumer market, and develops a targeted policy transmission mechanism model to dissect the multidimensional effects of tariffs on bilateral automotive trade flows, import commodity structure adjustment and domestic industrial operation, further verifying that long-term tariff barriers will curb independent innovation capacity and weaken the global competitive edge of domestic manufacturing.

Thirdly, utilizing the classic Armington model, Sino-X semiconductor trade commodities are categorized into high-end, mid-range and low-end segments to measure the variations of import share and weight after tariff escalation, which objectively reflects the unique supply and demand structure and import dependence of Y's semiconductor industry.

Fourthly, a multi-scenario simulation framework is constructed to quantify the fluctuation range of X Country's tariff revenue and predict its net adjustment scale, with relevant calculations showing that the cumulative tariff revenue of X Country in the next five years will reach \$353.98 billion.

Finally, selecting six representative macroeconomic indicators and adopting ridge regression to eliminate multicollinearity interference, the paper evaluates and predicts the medium and long-term economic negative shocks triggered by tariff policies, covering real GDP contraction, sustained CPI elevation and continuous deterioration of the unemployment rate.

Keywords

Bilateral Reciprocal Tariffs, Rotterdam Model, Armington Model, Grey Forecasting Model, Predictive Analytics, Ridge Regression

1. Introduction

Tariffs, as a vital component of a nation's tax system, serve not only as a stable source of fiscal revenue for countries worldwide but also as a core policy tool for regulating foreign economic and trade activities and implementing national trade strategies. The judicious application of tariff policies can establish appropriate market protection barriers, creating a stable development environment for domestic strategic emerging industries and infant industries while effectively countering the impacts of disorderly competition, monopolistic practices, and unreasonable trade coercion in international markets. However, excessive or improper use of tariff measures can trigger a series of negative effects. Abnormal tariffs—such as excessively high protective tariffs, discriminatory tariffs, or temporary tariff barriers—not only directly inflate the cost of imported goods, increase operational burdens on enterprises, and harm consumer welfare, but also undermine the fairness and transparency of global trade. They provoke retaliatory measures from trading partners, escalate trade frictions, severely disrupt the smooth operation of global industrial and supply chains, and run counter to the trend of economic globalization. Therefore, this paper aims to further analyze the impact of tariff policies on global trade and regional economies based on *X Country's* tariff data and global trade statistics. It will propose targeted recommendations and countermeasures based on the analysis results and the current development landscape.

2. Modeling and Solving

2.2 Modeling and solving Problem one

2.2.1 Modeling

When studying how tariff adjustments influence trade policy changes, most applied partial equilibrium or general equilibrium models commonly adopt the Armington assumption of differentiated exports between countries (Tong, 2006). The magnitude of its coefficients directly reflects the primary impact of *X Country's* tariff policy tools on the global economic landscape.

First, to accurately quantify the impact of *X Country's* tariff adjustments on *A Country's* soybean imports from the *X Country*, *Y Country*, and *Z Country*—both in terms of volume and structure—this study constructs a Rotterdam model within the international trade Armington framework (Luo & Jiang, 2014). This model measures *A Country's* soybean trade with these countries and assesses the effects of

X Country's tariff adjustments on their soybean industries. The specific model construction is detailed in Equation (1):

$$\text{weight}_i \log_{q_i/q_{i-1}} = \alpha_i \log Q + \sum_{j=1}^n \gamma_{ij} \log_{\text{price}_i/\text{price}_{i-1}} \quad (1)$$

Here, $i, j=1,2,3, n$, w_i , q_i , price_i representing the proportion of soybean imports from the *X Country*, *Y Country*, and *Z Country* respectively in *A Country's* total soybean imports, the import volume, and the import price ; $\log_{\text{price}_i/\text{price}_{i-1}}$ indicates the percentage increase in import prices ; α_i marginal expenditure share for soybean imports , γ_{ij} net effect on soybean import prices. To ensure the model accurately reflects real trade environments and preferences, the following constraints are applied to the aforementioned model: ①additivity, $\sum_{i=1}^n \alpha_i=1$, $\sum_{i=1}^n \beta_{ij}=0$, *A Country's* total soybean imports represent its total demand, which is equivalent to the combined exports from the *X Country*, *Y Country* and *Z Country*; ②homogeneity, $\sum_{j=1}^n \beta_{ij}=0$. *A Country's* demand for soybeans is relatively sensitive to price changes, but shows limited responsiveness to overall price fluctuations; ③symmetry. $\beta_{ij}=\beta_{ji}$, The substitution effect between soybeans and similar commodities is equal in pairs.

Secondly, since the soybean trade import and export data provided in the appendix primarily covers the period from 2020 to 2024, it constitutes a small sample size. Moreover, trade import and export volumes exhibit significant volatility influenced by multiple factors. To further accurately forecast the distribution of soybean export volumes and values among the *X Country*, *Z Country* and other countries following *X Country's* tariff adjustments, this study adopts an improved grey forecasting model inspired by the methodology of Yang Hualong et al. (Yang, Liu, & Zheng, 2011). The specific model construction steps are as follows:

(1) Set the original sequence for the model:

$$X^{(0)}=(X^{(0)}(1),X^{(0)}(2),\dots,X^{(0)}(n)) \quad (2)$$

(2) Generate a new sequence after performing first-order accumulation:

$$X^{(1)}=(X^{(1)}(1),X^{(1)}(2),\dots,X^{(1)}(n)) \quad (3)$$

(3) After accumulating the raw data, the randomness of the data is reduced. The sequence then exhibits an exponential growth pattern, leading to the establishment of a first-order linear differential equation for grey forecasting:

$$\frac{dX^{(1)}}{dt} + aX^{(1)}=u \quad (4)$$

Among these, a represents the development index, reflecting the trend of the original sequence's evolution; u represents the endogenous control index, reflecting the relationship between changes in various data points.

(4) Solve for the estimated parameters using the least squares method:

$$\hat{\alpha}=(B_{\mu=0}^T B_{\mu=0})^{-1} B_{\mu=0}^T Y_n \quad (5)$$

(5) The estimated equation for the original sequence obtained using the least squares method:

$$\widehat{X}^{(0)}(K+1)=\widehat{X}^{(0)}(K+1)-\widehat{X}^{(1)}(K), \quad k=0,1,\dots,n-1 \quad (6)$$

(6) Conduct a test for grade deviation:

$$\bar{\eta}=\sum_{k=2}^n \eta(k)/(n-1) \quad (7)$$

Finally, training was conducted using MSE as the loss function and the Adam optimizer, iterating for 500 epochs. The training loss was recorded at each iteration, and a loss curve was plotted for the constructed Rotterdam model to evaluate its convergence and fitting performance.

2.2.2 Solving

1. The current state of soybean trade between *A Country* and three other countries was analyzed using the Rotterdam model. Python software was employed to substitute soybean import and export data from *A Country*, *X Country*, *Y Country* and *Z Country*.

Table 1. Three Countries Account for a Share of Total Demand

Year	<i>X Country's</i> import Volume (10 kt)	<i>X Country's</i> share(%)	<i>Y Country's</i> import Volume(10 kt)	<i>Y</i> <i>Country's</i> share(%)	<i>Z Country's</i> import Volume(10 kt)	<i>Z</i> <i>Country's</i> share(%)
2020	2589.0	70.5	143.6	3.9	938.0	25.6
2021	3230.0	70.2	244.9	5.3	1125.7	24.5
2022	2953.0	68.4	48.9	1.1	1317.6	30.5
2023	2417.0	67.4	498.8	13.9	670.7	18.7
2023	2213.0	60.4	726.9	19.8	723.3	19.7

As shown in the chart above, prior to the implementation of the new *X Country's* tariff policy, *X Country* held the largest share in *A Country's* soybean import market but had been experiencing a continuous decline, dropping from 70.5% in 2020 to 60.4% in 2023. *Z Country's* share of soybean imports simultaneously declined from 25.6% in 2020 to 19.7%, yet it maintained a moderate market position. Meanwhile, *Y Country's* soybean import share demonstrated a steady upward trend, rising from 3.9% in 2020 to 19.8%. This shift in market dynamics indicates that, anticipating *X Country's* tariff policies, *A Country's* major soybean buyers have proactively adjusted their import structure, further shifting toward the South American market. By optimizing supply chain arrangements, they aim to mitigate potential supply risks and trade barriers.

2. Solve the distribution of soybean export volumes and values for *X Country*, *Z Country*, and *Y Country* using a grey forecasting model. Based on the aforementioned analytical conclusions, to further forecast the market distribution trends of soybean export volumes and values for *X Country*, *Z Country*, and *Y Country* under the macroeconomic context of the *X Country's* persistently implementing its

so-called “reciprocal tariff” policy, this study continues to employ Python tools to construct a grey prediction model. Existing statistical data serves as input variables to achieve quantitative predictive analysis of the export scale and structure for these three countries. First, substitute the data from the appendix into equations (2), (3), (4), and (7) to calculate the parameters required for the grey prediction model. Substitute the obtained results and appendix data into equation (6).

According to the forecast results shown in the chart above, *A Country's* soybean imports from *X Country* have been on a continuous downward trend since January 2025. By October 2025, the U.S share of *A Country's* soybean import market had dropped to 0%, representing a significant year-on-year decline compared to the 541,434 tons imported during the same period in 2024.

2.3 Modeling and Solving

2.3.1 Modeling

First, *X Country* is the world's second-largest automotive market and the largest importer of vehicles, with *J Country* serving as the primary supplier to the *X Country's* market. However, following the implementation of new *X Country's* tariff policies, the volume of imported vehicles into *X Country* has continued to decline, while *J Country* now faces heightened tariff barriers. Based on this context, this paper employs a log-linear import demand function model to forecast the impact of sustained *X Country's* tariff policies on both *J Country's* and the *X Country's* domestic automotive industries. The specific model is presented in Equation 8:

$$\log Q = X w + b \quad (8)$$

Here, Q represents *X Country's* automotive demand, w denotes the demand elasticity coefficient, X signifies *X Country's* demand for vehicles from various sources, and b represents the disturbance term for other factors.

Furthermore, the simulated tariff policy affects aggregate demand through the price transmission channel: tariffs raise the effective price of *J Country's* automobiles, pushing up the overall price index of the *X Country's* automotive market. This, in turn, contracts the total size of the *X Country's* automotive market based on price elasticity of demand. The full chain of transmission unfolds as follows: tariff policy implementation impacts prices, which then influence aggregate demand for *X Country's* automobiles, ultimately reshaping the entire automotive market structure. The specific quantitative modeling process is as follows:

(1) Assuming all tariffs are passed on to the final price, calculate the automobile price index after the implementation of the new tariff policy:

$$P_{j1} = P_{j0}(1 + \beta t) \quad (9)$$

(2) Calculate the relative rate of change for the automobile price index:

$$\frac{\Delta P}{P_0} = \frac{s_{j0} P_{j0} t}{I_0} \quad (10)$$

(3) Adjust total *X Country's* automobile demand based on relative changes in price indices and demand

elasticity:

$$Q_1 = Q_0 \cdot \left(1 + E_d \frac{\Delta P}{P_0}\right) \tag{11}$$

(4) Scale the projected sales volumes from each source proportionally to ensure the total aligns with the adjusted overall demand:

$$Q_{u1} = Q_1 \cdot \frac{s_{u0} P_{u0}}{I_1} \tag{12}$$

Here, β represents the pass-through coefficient, I_1 represents weighted average price, Q_1 represents total demand by source location price weight allocation.

Finally, the Adam optimizer was employed to train the constructed model, with training loss recorded at each iteration.

2.3.2 Solving

First, we analyze the current competitive landscape’s of *J Country’s* automobiles in the *X Country’s* market using a linear aggregate demand function model. Based on the *X Country’s - A Country’s* automotive trade panel data from 2015 to 2024 selected for this study, Python is employed to substitute the standardized data into equations (8) to (12), enabling quantitative simulation of market effects under reciprocal tariff policies. With tariff adjustment magnitude as the core explanatory variable, incorporating key parameters such as *J Country’s* automakers' non-tariff countermeasures, price pass-through coefficients, and demand price elasticity, the study outputs projections for the scale of *J Country’s* automotive exports to the *X Country* and the structure of the *X Country* automotive import market. Specific results are presented in Figure 1.

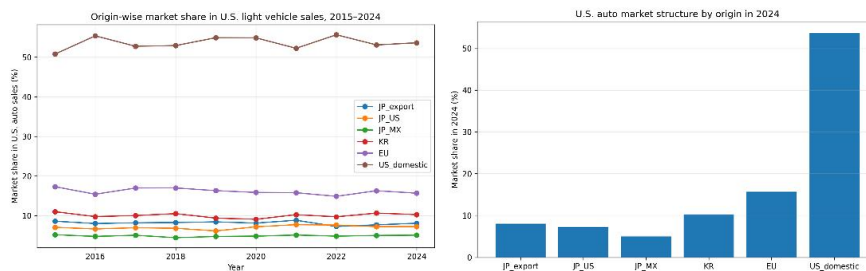


Figure 1. Automotive Market Share Chart

As shown in the figure, during the period before the *X Country* implemented its “reciprocal tariff” policy, *J Country’s* automobiles had already captured a significant share of the *X Country’s* market, though American domestic vehicles maintained their dominant position. Following the official implementation of the new tariff policy in April 2025, *J Country’s* automakers faced substantially heightened tariff barriers for exports to the *X Country*, directly leading to increased export costs and compressed profit margins.

Secondly, without further verifying the accuracy of the model solutions or the logical rigor of the

economic transmission effects, this study employed the Adam optimizer to continuously adjust and optimize the model during training. By seeking optimal parameters and plotting the loss curve for the linear import demand model, we assessed the convergence and fitting performance of the constructed linear demand function model and economic transmission model.

2.4 Modeling and Solving

2.4.1 Modeling

First, based on the practical orientation and adjustment trends of *X Country's* semiconductor industry policies, three differentiated policy scenarios are established to form comparative benchmarks. The baseline scenario (no additional intervention) reflects the semiconductor manufacturing and trade landscape under spontaneous market regulation without imposing extra tariffs or subsidies. The high-tariff scenario simulates the direct impact of pure import restriction policies on trade flows and production costs by imposing targeted tariffs on Chinese chips at different process nodes. The tariff-plus-subsidy composite scenario combines the high-tariff policy with domestic *X Country's* semiconductor industry subsidies, validating the dual policy logic of import suppression and domestic support to analyze the cumulative effects of policy combinations on market competition. By cross-referencing these three scenarios.

Second, to quantify the distribution mechanism of chip trade under policy shocks, the Armington trade model is introduced as the core analytical tool. Based on the characteristics of incomplete substitutability among similar chips across different countries, the import and export weight coefficients of *A Country* and other supplier nations in the *X Country's* chip market are calculated. This clearly reveals the transmission mechanism whereby tariff-induced price changes lead to market share restructuring, thereby quantifying the specific impact of policies on *A Country's* chip trade volume and market share. The specific calculation formula is as follows:

$$W_{n,c} = A_{n,c} \cdot P_{n,c}^{-\rho} \quad (13)$$

$$\text{RiskIndex} = W_{IDR} \cdot IDR + W_{CDR} \cdot CDR + W_{HHI} \cdot HHI \quad (14)$$

Here, $A_{n,c}$ represents the preference weight, ρ denotes the substitution elasticity, W_{IDR} represents import dependency, W_{CDR} indicates the degree of dependence on *A Country*, W_{HHI} represents the concentration of supply.

Finally, substitute the filtered data into the formula to calculate the results for each indicator, and further analyze the impact of *X Country's* tariff adjustments on *A Country's* high-, medium-, and low-end chip manufacturing and trade through quantitative metrics.

2.4.2 Solving

First, using Python software, we calculated the domestic and imported shares of *X Country's* semiconductor chips under three distinct policy scenarios based on the filtered Sino-*X Country's* semiconductor chip trade data. The quantified results were visualized as shown in Figure 2. Second, we substituted the quantified data into Formula (13) to compute the risk coefficients for high-, medium-, and low-end chips under different national policies.

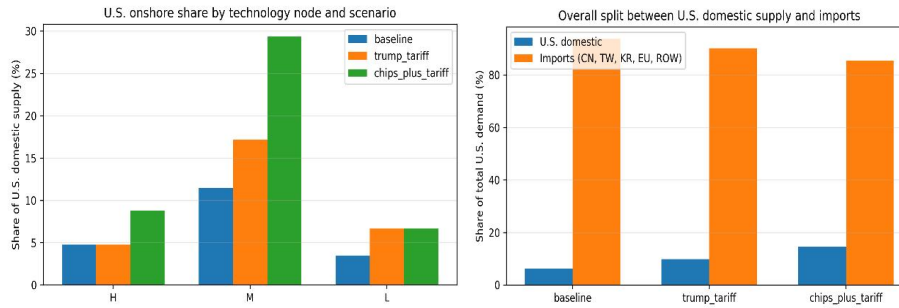


Figure 2. X Country's Domestic vs. Imported Chip Market Share Chart

As shown in the visualization above, the domestic supply share of mid-range semiconductor chips in *X Country* consistently remains the highest across all three policy scenarios. This indicates that mid-range chips in the *X Country's* benefit from both mature domestic industrial chain support capabilities and the absence of the extreme R&D costs and production capacity barriers associated with high-end chips. In contrast, the high-end chip sector remains constrained by R&D barriers and equipment dependencies, preventing the formation of a dominant domestic supply advantage. It continues to rely on external core suppliers such as Taiwan and South Korea. Low-end chips, hindered by higher domestic production costs and limited profit margins, exhibit a relatively low share of domestic capacity. This results in an industrial structure characterized by mid-range dominance and reliance on external sources for both high-end and low-end segments. By imposing targeted tariffs on Chinese chips, *X Country* raises the cost barrier for Chinese chip exports to the *X Country's*, weakening their price competitiveness. This indirectly restricts the scale of Chinese chip exports to the *X Country's* and their market penetration, reflecting that the impact of tariff policies on the chip industry must be assessed holistically, considering both technological complexity and industrial foundations.

2.5 Modeling and Solving

2.5.1 Modeling

First, construct a multi-scenario tariff revenue measurement model. Using the baseline scenario (current benchmark tariff rates) as the reference benchmark, precisely calculate the changes in import volumes following the implementation of reciprocal tariff policies. Quantify the total tariff revenue scale for *X Country* under both scenarios to establish a basis for comparing pre- and post-policy revenue. Simultaneously, we calculate the contribution share and marginal change of various commodities within total tariff revenue, clarifying the differential impact of different product categories on the policy's revenue effects. Second, considering the complex nature of tariff policy impacts and the limited data sample size, we further employ a grey forecasting model to scientifically predict the net change in tariff revenue during the Trump administration's second term. The specific model formula is as follows:

$$\text{Revenue} = \text{ImportValue} \cdot \text{TariffRate} \quad (15)$$

Here, *ImportValue* represents total imports, *TariffRate* represents the tariff rate.

2.5.2 Solving

First, based on the constructed model, the total *X Country's* import value from the annex data was substituted into Formula (15) to calculate *X Country's* tax revenue under both the baseline scenario (base tariff rates) and after implementing reciprocal tariff policies. Contributions to *X Country's* tax revenue from different product categories were then categorized and measured, with the visualized results shown in Figure 3. Second, to further illustrate the magnitude of changes in *X Country's* import scale and revenue under the reciprocal tariff policy, the calculated results were plotted as an annual indicator heatmap for 2024-2028, as shown in Figure 3.

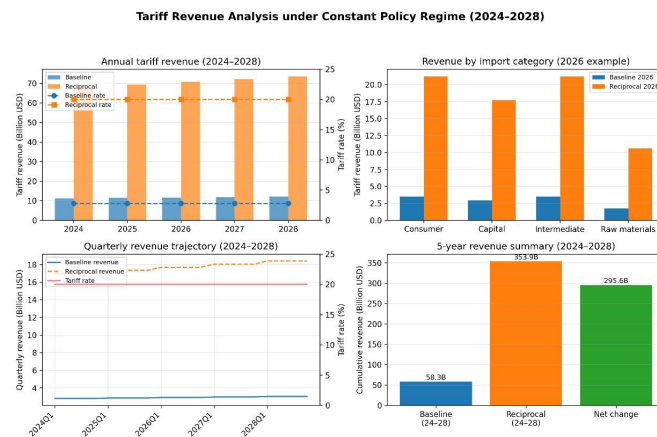


Figure 3. Tariff Revenue Analysis Dashboard

The visualization results above indicate that *X Country's* tariff revenue will exhibit sustained and steady growth from 2024 to 2028. From a medium-term perspective, tariff revenue under both policy scenarios increases annually in tandem with natural growth in import volumes, with cumulative total tariff revenue over five years projected to reach \$353.98 billion. In the short term, quarterly tariff revenue trajectories align with annual trends, exhibiting continuous upward momentum. This indicates that during the second term of the Trump administration, tariff revenue will achieve phased growth driven by the rate-hiking effect of reciprocal tariff policies.

2.6 Modeling and Solving

2.6.1 Modeling

First, to precisely quantify the short-term and medium-term impacts of *X Country's* tariff adjustments on its economic development, this paper constructs a multi-factor macroeconomic shock transmission model using six economic indicators: GDP, CPI, employment rate, manufacturing percentage, fiscal deficit, and manufacturing reshoring.

Second, given that the selected indicators measure *X Country's* economic development from distinct dimensions, to mitigate multicollinearity issues among them and further reduce prediction errors relative to actual outcomes, a ridge regression equation is employed to forecast changes in *X Country's* GDP, CPI, and unemployment rate over the next five years resulting from reciprocal tariff policies [4].

The specific model construction formula is as follows:

$$\hat{\beta}_\lambda = (X^T X + \lambda I_k)^{-1} X^T Y \tag{16}$$

Finally, using the model constructed above, we calculate the repatriation advantages for high-end, mid-range, and low-end consumer goods, as well as advanced semiconductors in manufacturing, under the context of *X Country's* tariff adjustments. This further assesses the extent to which *X Country's* counter-tariff policies influence the return of manufacturing operations.

2.6.2 Solving

First, a quantitative analysis model was constructed using Python, incorporating six core economic indicators: GDP growth rate, CPI inflation rate, employment rate, manufacturing output share, fiscal deficit scale, and manufacturing reshoring feasibility score. The model systematically calculated the magnitude and relative change indices of each indicator under different tariff rate gradients, quantifying the relationship between tariff intensity and indicator responses. Specific calculation results are shown in Figure 4.

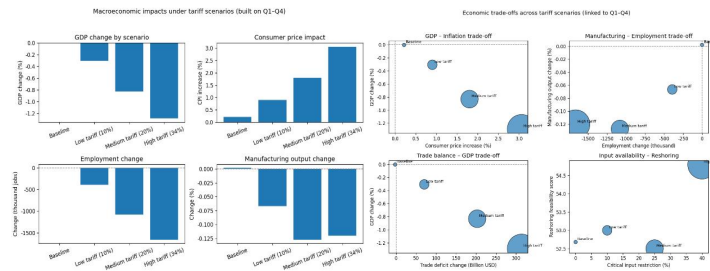


Figure 4. Index Change Chart

Second, to visually illustrate the varying sensitivity of different indicators to tariff policies, a heatmap visualizes the distribution of change intensity across economic indicators at different tariff levels. Concurrently, integrating historical data with policy scenario assumptions, an indicator forecasting model was constructed to provide forward-looking projections for three core macroeconomic indicators: the *X Country's* GDP growth rate, CPI inflation rate, and unemployment rate over the next five years. These visualizations reflect the short-term impact and medium-term evolution of the *X Country's* reciprocal tariff policy on its economy, as shown in Figures 4 and 5.

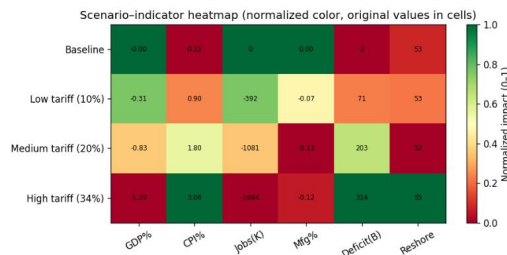


Figure 5. Relevant Metrics Heatmap

Finally, focusing on the core driver of manufacturing reshoring under tariff policies, this study

quantifies the reshoring advantages for different product categories under *X Country's* tariff adjustments. This includes four typical product types: low-end, mid-range, and high-end consumer goods, along with advanced semiconductors. The analysis calculates the cost advantage coefficient for reshoring, the feasibility of production capacity substitution, and the long-term profit potential for each product category. Specific results are presented in Figure 5.

3. Conclusions

This paper concludes that *X Country's* reciprocal tariff measures exert far-reaching and heterogeneous impacts on international trade flows, sectoral industrial structures, and regional economic stability, as evidenced by the systematic analysis of five core research questions. Collectively, the findings reveal that while reciprocal tariffs may generate short-term tariff revenue gains for *X Country*, their long-term costs—including distorted trade patterns, weakened industrial competitiveness, and macroeconomic shocks—outweigh these marginal benefits, highlighting the inefficiency of tariff-based trade policies as a tool for regulating international trade and boosting domestic economic performance.

Regarding agricultural trade, the estimation results based on the Rotterdam model demonstrate that *X Country's* tariff adjustments significantly alter *A Country's* soybean import elasticity from its three key suppliers, leading to reshaped trade flows in the global soybean market. The grey forecasting model further confirms that fluctuating tariff policies will continue to introduce uncertainty into soybean export volumes and trade values, affecting the stability of both exporting and importing countries' agricultural sectors and supply chains. For the automotive industry, the log-linear import demand function and policy transmission model indicate that *X Country's* tariffs not only disrupt *X Country's* - *Z Country's* automotive trade and adjust import structures but also impose long-term constraints on the *X Country's* domestic automotive industry, hampering independent innovation and eroding its global competitive edge.

In the semiconductor sector, the Armington model-based analysis, which categorizes Sino- *X Country's* semiconductor trade into high-end, mid-range, and low-end chips, uncovers distinct structural characteristics of *A Country's* semiconductor imports—specifically, the varying degrees of import weight changes under new tariffs, reflecting *A Country's* differentiated dependence on *X Country's* semiconductor products and potential adjustments in its supply chain strategy. Meanwhile, the multi-scenario simulation confirms that *X Country's* tariff revenue will undergo significant fluctuations, with a projected five-year cumulative total of \$353.98 billion; however, this revenue growth is accompanied by indirect costs such as reduced trade volume and increased domestic production costs.

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