Quantitative Assessment of the Multi-Dimensional Impacts of U.S. "Reciprocal Tariffs" Policy: A Comprehensive Modeling Approach

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Abstract. The 2025 U.S. "reciprocal tariffs" policy dramatically increased the U.S. trade-weighted average tariff rate from 2.44% to 20.11%, fundamentally reshaping global trade patterns. This paper develops an integrated quantitative framework to systematically evaluate the multi-dimensional impacts of this policy across three key sectors and on overall economic welfare. For soybean trade, we integrate a trade gravity model with partial equilibrium analysis, finding that U.S. soybean exports to China would virtually exit the market under 25% tariffs, while Brazilian market share would increase from 70.4% to over 95%. For automobiles, a tri-channel supply chain model and two-stage dynamic game framework reveal that Japanese direct exports would decrease by 26%, with Mexican production share rising from 25% to 40%, indicating multinationals rational choice of "circuitous production" rather than manufacturing reshoring. For semiconductors, a tiered market model with system dynamics simulation demonstrates that a balanced subsidy-centric strategy achieves optimal comprehensive performance (score 0.778) compared to tariff-centric approaches (0.722). Tariff revenue forecasting using an industry heterogeneity elasticity model with Monte Carlo simulation shows a net present value of only $32 million and Policy Efficiency Index of 0.05, indicating economic inefficiency. Our findings suggest that unilateral tariff protection is costly and inefficient, while comprehensive approaches integrating tariffs with industrial policies better balance economic efficiency and national security.

Keywords: Reciprocal Tariffs; Trade Gravity Model; Policy Efficiency Index; Game Theory

1 Introduction

1.1 Policy Background

In April 2025, the Trump administration implemented "Reciprocal Tariffs," imposing a 10% baseline tariff on all partners plus additional tariffs on ~60 countries with U.S. trade deficits. This surged the U.S. trade-weighted average tariff from 2.44% to 20.11%, the highest since 1933. While tariffs can protect domestic industries and

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generate revenue, excessively high tariffs disrupt trade, trigger retaliation, and harm growth. The policy challenges WTO principles and affects three key sectors with distinct structures: soybeans (low substitution elasticity), automobiles (complex supply chains), and semiconductors (technological stratification and security implications).

1.2 Literature Review and Research Gap

The gravity model, introduced by Tinbergen [1], remains the foundation for analyzing bilateral trade flows. Anderson and van Wincoop [2] provided theoretical microfoundations, showing that borders reduce trade by 20-30%. The Armington assumption [3] explains source-country differentiation in agricultural trade through CES utility functions. Bergstrand et al. [4] extended this framework by incorporating firm heterogeneity and increasing marginal costs.

For policy evaluation, Francois and Hall [5] developed partial equilibrium techniques for sector-specific analysis. Bagwell and Staiger [6] formalized the terms-of-trade theory of trade agreements. Sterman [7] introduced system dynamics for modeling complex economic adjustments. Feenstra [8] emphasized product-level heterogeneity in trade analysis. Grossman and Helpman [9] demonstrated that strategic government-firm interactions determine policy outcomes. Head and Mayer [10] provided guidance on theoretically-However, existing studies examine sectors in isolation or assume homogeneous tariff responses. The 2025 "reciprocal tariffs" policy, with unprecedented scope and magnitude, requires an integrated framework capturing: (1) industry-specific heterogeneity, (2) dynamic supply chain adjustments across sectors, and (3) trade-offs between economic efficiency and national security.

2 Methodology

2.1 Core Modeling Framework

Our integrated modeling framework consists of four interconnected modules, each tailored to specific analytical requirements while maintaining conceptual consistency.

Trade Gravity Model with Partial Equilibrium.

For soybeans, we employ a gravity model with tariff variables, log-linearized as:

$$\ln(T_{ij}) = \alpha_0 + \alpha_1 \ln(GDP_i) + \alpha_2 \ln(GDP_j) + \alpha_3 \ln(Dist_{ij}) + \alpha_4 \tau_{ij} + \epsilon_{ij} \quad (1)$$

Based on 2020-2024 historical data, our calibrated parameters show a tariff elasticity of -2.34 (significant at 1% level) The model explains 99.05% of variance in trade flows (R^2=0.9905).

To capture substitution effects among source countries, we incorporate the Armington CES utility function, which yields market share allocation as:

$$s_i = \frac{(P_i^{cif})^{-\sigma}}{\sum_{j=1}^{3}(P_j^{cif})^{-\sigma}} \tag{2}$$

with substitution elasticity parameter $\sigma = 1.8$ calibrated through historical data.

Two-Stage Dynamic Game Model.

For automobile trade, where strategic interactions between governments and firms are central, we develop a two-stage complete information dynamic game model. In Stage 1, the U.S. government selects tariff rate τ to maximize its welfare function:

$$\max_{\tau} W_{US}(\tau) = CS_{US} + PS_{US} + TR_{US} - PC_{US} \tag{3}$$

where CS_{US} is consumer surplus, PS_{US} producer surplus, TR_{US} tariff revenue, and PC_{US} political costs

In Stage 2, after observing τ, Japan chooses a strategy combination $s = (\alpha, \beta, \gamma)$ representing production capacity transfer, technology upgrade, and price concession. Japan maximizes:

$$\max_{\alpha,\beta,\gamma} W_{JP}(\tau) = \pi_0(\tau) + \Delta\pi_\alpha(\alpha) + \Delta\pi_\beta(\beta) + \Delta\pi_\gamma(\gamma) - [C_\alpha(\alpha) + C_\beta(\beta) + C_\gamma(\gamma)] \tag{4}$$

where $\Delta\pi$ terms represent incremental profits from each strategy and C terms represent adjustment costs.

Japanese cars enter the U.S. market through three channels: direct exports, production in the U.S., and production in Mexico. The cost structures differ across channels, incorporating production costs, shipping, tariffs, and parts sourcing.

Tiered Market Model with System Dynamics.

For semiconductors, we classify chips into three tiers based on process maturity (M), U.S. manufacturing dependency (D), and demand elasticity (ε), as shown in Table 1.

Table 1. Chip Market Classification and Key Parameters

Chip Tier	Process Maturity (M)	Mfg. Dependency (D)	Demand Elasticity (ε)
High-End	Low (0.1-0.4)	Low (0.1-0.3)	-0.3
Mid-Range	Medium (0.4-0.7)	Medium (0.3-0.6)	-0.7
Low-End	High (0.7-1.0)	High (0.6-1.0)	-1.2

U.S. domestic demand follows a nonlinear function incorporating policy variables, and domestic supply dynamics incorporate feedback loops. The comprehensive evaluation uses a tri-dimensional scoring system with weights reflecting the industrys "technology-first" nature: Economic (E)=0.3, Security (S)=0.4, Process Feasibility (T)=0.3:

$$Total = 0.3E + 0.4S + 0.3T \tag{5}$$

Economic score incorporates profit, cost, and market share changes:

$$E = 0.5 \cdot \frac{\pi_{\text{post}}}{\pi_{\text{pre}}} + 0.3 \cdot \left(1 - \frac{C_{\text{post}}}{C_{\text{pre}}}\right) + 0.2 \cdot \frac{\text{MS}_{\text{domestic, post}}}{\text{MS}_{\text{domestic, pre}}} \quad (6)$$

Industry Heterogeneity Elasticity Model with Monte Carlo Simulation.
For tariff revenue forecasting, we develop an industry-specific elasticity model that accounts for heterogeneous responses across sectors. The short-term comprehensive response coefficient for industry i is:

$$\theta_i^{short} = \alpha_i \cdot \eta_i + \beta_i \cdot \delta_i \quad (7)$$

where α_i is demand elasticity, η_i price sensitivity, β_i adjustment speed, and δ_i tariff pass-through rate.

Medium-term dynamics incorporate substitution effects and trade diversion, leading to the following import volume equation:

$$Q_i^{medium} = Q_i^0 \cdot (1 - \theta_i^{short} - \kappa_i \cdot \Delta\tau_i + D_i + A_i + \gamma_i \cdot \Delta e) \quad (8)$$

We employ Monte Carlo simulation with 1000 iterations, sampling key parameters from normal distributions. Policy efficiency is evaluated using the Policy Efficiency Index (PEI):

$$PEI = \frac{PV}{\text{Cost}}, \quad PV = \sum_{t=1}^{5} \frac{\Delta R_t}{(1+r)^t} \quad (9)$$

2.2 Data Sources

This study employs multiple data sources: soybean trade data (2023 baseline) from Chinas National Bureau of Statistics and General Administration of Customs (U.S. imports: 24.174 million tons, Brazil: 69.95 million tons, Argentina: 1.993 million tons); automobile trade data from JAMA 2024 U.S.-Japan Auto Trade Report (baseline channel shares: direct exports 30%, U.S. production 45%, Mexican production 25%); semiconductor industry data from SIA reports and USITC trade statistics; macroeconomic data from IMF and World Bank; tariff revenue data from U.S. Trade & Tariff Database.

3 Empirical Results

3.1 Soybean Trade: Trade Diversion and Market Restructuring

Using the calibrated gravity model (Equation 2) with tariff elasticity -2.34, we simulate three tariff scenarios with 1000 Monte Carlo iterations. The baseline scenario (U.S. 0%, Brazil & Argentina 5%) reflects current conditions, with U.S. market share at 24.3%. Under the escalation scenario (U.S. 15%, Brazil & Argentina 5%), U.S. exports drop to effectively zero, completely losing market competitiveness. In the mitigation scenario where all three countries face similar competitive conditions, Brazilian dominance persists due to cost advantages. The resulting market shares under each scenario are summarized in Table 2.

Table 2. Soybean Market Shares Under Alternative Tariff Scenarios

Scenario	U.S. Share	Brazil Share	Argentina Share
Baseline (0%/5%/5%)	24.3%	70.4%	2.0%
Escalation (15%/5%/5%)	<0.1%	95.2%	4.8%
Mitigation (equal tariffs)	18.5%	76.3%	5.2%

Brazil captures ~95% of U.S. lost share. Trade creation minimal given stable Chinese demand (119.69M tons). Tariffs restructure shares among existing suppliers rather than creating new flows.

3.2 Automobile Trade: Strategic Responses and Supply Chain Restructuring

Channel competitiveness reverses at 25% tariffs: direct exports become least competitive, Mexico production most competitive. Using demand elasticity $\varepsilon_d = -1.2$. Mexico channel expands from 25% (S1) to 53% (S5); direct exports contract from 30% to 2%. U.S. production initially rises from 45% to 50% then declines. Game equilibrium shows U.S. optimal tariff ~25%. Japan's optimal response: 66.2% capacity transfer (to Mexico), 33.8% technology upgrading; price concessions suboptimal.

3.3 Semiconductor Industry: Balancing Efficiency and Security

We simulate three policy scenarios over 2025-2030: Scenario A (Status Quo/Baseline) with moderate tariffs and CHIPS Act subsidies; Scenario B (Tariff-Centric) with high average tariffs (20%); Scenario C (Subsidy-Centric) with low tariffs (5%) and enhanced subsidies.

Table 3. Comprehensive Policy Evaluation Results for Semiconductors

Policy Scenario	Economic Score (E)	Security Score (S)	Process Score (T)	Total Score
A: Status Quo	0.70	0.65	0.75	0.698
B: Tariff-Centric	0.65	0.80	0.70	0.722
C: Subsidy-Centric	0.80	0.70	0.85	0.778

A comparative evaluation of the three policy scenarios is presented in Table 3. Scenario B achieves the highest Security Score (0.80) through reduced foreign dependency and strict controls, but economic efficiency suffers (E=0.65) due to increased costs and trade reduction, while process advancement is hampered (T=0.70) by disrupted global R&D collaboration. Scenario C yields the highest Total Score (0.778), excelling in Economic (0.80) and Process Feasibility (0.85) dimensions. Subsidies directly stimulate R&D and capacity investment, accelerating technology maturation and reducing costs.

Simulation of high-end chip dynamics shows dramatic supply increases (361.5% by 2030) driven by import substitution, but capacity contraction (-33.1%) reveals the unsustainability of relying solely on protective tariffs without concurrent investment incentives. Figure 1 illustrates the trends in supply, capacity, and profit for domestic semiconductor industry.

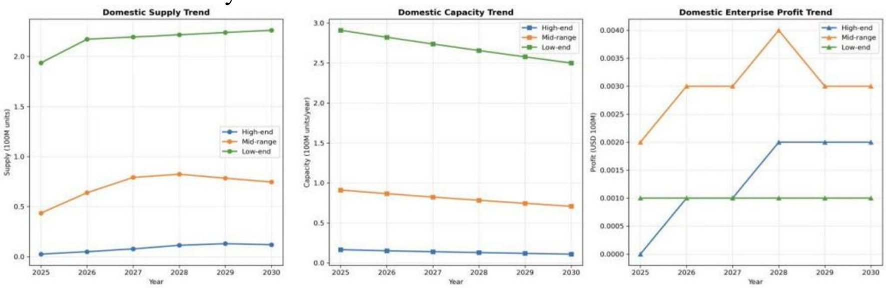

Fig. 1. Trends of Supply, Capacity, and Enterprise Profit in Domestic Semiconductor Industry

Tariffs provide the strongest expansion incentive for low-end chips (expansion coefficient: 0.35), where processes are mature and capital barriers lower. The comprehensive score trends across economic, security, and process dimensions are shown in Figure 2.

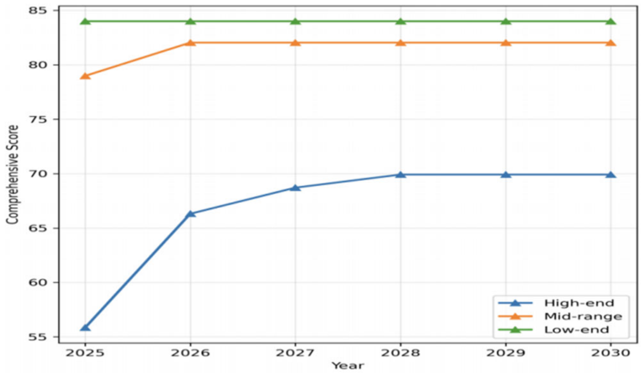

Fig. 2. Comprehensive Score Trend (Economic+Security+Process)

Security risk assessment reveals persistent high risk for high-end chips (1.000 in 2030), validating concerns about strategic dependencies . Self-sufficiency rates projected for 2030 (High-End: 272.7%; Mid-Range: 838.2%; Low-End: 493.9%) reflect the denominator effect of export controls restricting legal import avenues rather than genuine production capacity.

3.4 Tariff Revenue: Minimal Net Gains and Policy Inefficiency

Applying the industry heterogeneity elasticity model with Monte Carlo simulation (1,000 iterations), we forecast U.S. tariff revenue changes for 2025–2029. The results show a pattern of initial increase followed by decline: net revenue rises modestly to about $0.10 billion in 2025–2026, then gradually falls to $0.04 billion by 2028–2029 as trade diversion intensifies. The present value of net tariff revenue over the five years is only $32 million, while total policy costs (welfare losses and administrative expenses) reach $663 million. This yields a Policy Efficiency Index (PEI) of 0.05—far below 1.0—demonstrating that the "reciprocal tariffs" policy is economically inefficient, with costs far exceeding benefits. Figure 3 compares baseline and policy scenario revenues and illustrates the uncertainty in net changes.

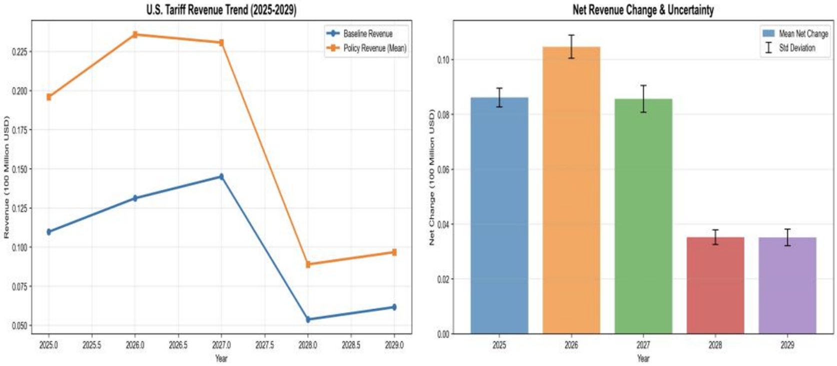

Fig. 3. Trend Comparison and Net Variation Uncertainty of U.S. Tariff Revenue 2025-2029

Monte Carlo simulation shows standard deviations of annual net changes ranging from 260,000to490,000, indicating robust predictions. Narrow 95% confidence intervals suggest the model is relatively insensitive to parameter fluctuations, and all annual mean confidence intervals do not cross zero, confirming that net changes, though minimal, remain positive.

3.5 Comprehensive Economic Impact: Reshoring vs. Welfare Loss

The Manufacturing Reshoring Index (MRI), combining output value, employment, capital investment, and self-sufficiency rate, shows an increase from 0.28 (short-term) to 0.38 (medium-term). Reshoring probability, estimated via Logit model (AUC=0.964), rises from 65.2% to 78.5%.

However, key parameter elasticities reveal vulnerabilities: policy uncertainty elasticity of -0.61 indicates that policy stability is a critical constraint on reshoring. Core PCE elasticity of ±9.5% shows domestic demands impact is more sensitive than initially estimated. The manufacturing employment change rate (+2.1% medium-term) is partially offset by job losses in distribution sectors, resulting in negligible net employment effects.

4 Discussion and Policy Implications

4.1 Synthesis of Findings

Three consistent patterns emerge: (1) Tariffs restructure existing trade rather than create new activity—soybeans to Brazil, autos to Mexico, semiconductors reconfigured not reshored. (2) Industry heterogeneity matters: agriculture, autos, and semiconductors respond differently. (3) Dynamic adjustments attenuate short-term effects. Minimal revenue gain (PV=$32M) and low efficiency (PEI=0.05) challenge fiscal rationale; Laffer curve logic applies.

4.2 Policy Implications

1.Industry-specific calibration: Uniform tariffs ignore heterogeneity. Semiconductor policy differs fundamentally from agriculture.

2.Dynamic considerations: Static analysis overstates benefits; evaluation must incorporate multi-year adjustments.

3.Policy mix optimization: Tariffs alone underperform balanced tariff-subsidy strategies (0.722 vs. 0.778).

4.International coordination: Unilateral tariffs trigger retaliation and diversion; negligible net employment and "circuitous production" demonstrate protectionism's limits.

5.Efficiency-security trade-offs: Balanced approaches achieve both objectives simultaneously.

5 Conclusion

This paper develops an integrated framework (gravity, partial equilibrium, game theory, system dynamics, Monte Carlo) to evaluate 2025 U.S. "reciprocal tariffs" across sectors.

Key findings: (1) Soybean trade favors Brazil at U.S. expense, minimal trade creation. (2) Auto supply chains shift to Mexico, not reshoring; Japanese direct exports -26% at 25% tariffs. (3) Semiconductor tariff-subsidy mix outperforms tariffs alone (0.778 vs. 0.722). (4) Net tariff revenue gains minimal (PV=$32M), PEI=0.05. (5) Manufacturing reshoring increases (MRI 0.28→0.38) but net welfare negative.

Main implication: Unilateral tariff protection is costly; comprehensive approaches integrating tariffs with industrial policies and international coordination better balance efficiency and security. Future policy must consider industry heterogeneity, dynamic adjustments, and international cooperation.

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