# Tariffs, Trade Policy Uncertainty, and US Macroeconomic Performance

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**Abstract**

We develop a quantitative two-country open-economy Dynamic Stochastic General Equilibrium (DSGE) model to analyze the macroeconomic consequences of unilateral and retaliatory tariff policies for the United States. The model features Calvo-style nominal rigidities, endogenous capital accumulation, non-homothetic trade preferences, and a novel tariff uncertainty channel modeled as a regime-switching process over the policy rate. Bayesian estimation using US–Rest-of-World quarterly data (1990Q1–2025Q4) reveals that a permanent 10-percentage-point increase in the US average tariff rate reduces steady-state real GDP by 0.8 percent, depresses aggregate investment by 3.1 percent, and raises the consumer price index by 1.4 percent. When foreign retaliation is incorporated, the output loss nearly doubles to 1.5 percent. Trade policy uncertainty alone—absent any realized tariff change—generates output contractions of 0.3–0.6 percent via elevated precautionary savings and depressed import demand. Sectoral decomposition reveals that manufacturing, agriculture, and tradeable services bear disproportionate adjustment costs. Our welfare analysis shows that a phased multilateral liberalization Pareto-dominates unilateral protection from the perspective of the US representative household.

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# 1 Introduction

The resurgence of protectionist trade policy as an instrument of economic statecraft constitutes one of the defining macroeconomic developments of the past decade. Since 2018, the United States has enacted successive waves of import duties—targeting steel and aluminum under Section 232, Chinese goods under Section 301, and a broader array of trading partners under reciprocal tariff schedules—culminating in effective import-weighted tariff rates that reached their highest levels since the interwar period by 2025. Understanding the general-equilibrium consequences of these policies for aggregate output, inflation, investment, and welfare requires a modeling framework capable of capturing the rich interaction between trade flows, nominal rigidities, monetary policy, and forward-looking expectations (Stolper and Samuelson, 1941; Krugman, 1980; Amiti et al., 2020; Acosta et al., 2026).

Indeed, international trade has long been regarded as an important source of economic growth, productivity, and consumer welfare. By allowing countries to specialize according to comparative advantage, trade can increase the efficiency with which resources are allocated while expanding the variety of goods available to consumers. Tariffs, however, alter these incentives by raising the domestic price of imported goods and protecting competing domestic producers. The macroeconomic consequences of tariffs therefore extend beyond the directly affected industries, potentially influencing consumption, investment, productivity, employment, inflation, exchange rates, trade flows, and aggregate output. The relationship between tariffs and macroeconomic performance has consequently remained an important issue in both economic theory and public policy (Smith, 1776; Bhagwati et al., 1963; Gros, 1987; den Besten and Kanzig, 2026).

The debate has acquired renewed significance following the substantial increase in U.S. tariffs beginning in 2018. After several decades characterized broadly by declining trade barriers, the United States introduced tariffs on a wide range of imported goods, particularly from China, while major trading partners responded with retaliatory measures. One of the central questions in evaluating tariffs is therefore who ultimately bears

their economic cost. Standard trade theory suggests that the incidence of a tariff can be shared between domestic consumers and foreign exporters, depending partly on market power and the elasticity of international demand and supply. Empirical evidence from the 2018 U.S. tariffs, however, indicates substantial pass-through of tariffs into domestic import prices (Ricardo, 1817; Heckscher, 1919; Amiti et al., 2019; Fajgelbaum and Mandelman, 2020).

The effects of tariffs are not limited to prices and consumer welfare. Because modern production frequently depends on imported intermediate inputs, tariffs can increase firms' production costs and alter investment and supply-chain decisions. Retaliatory tariffs can simultaneously reduce foreign demand for U.S. exports, creating additional pressures on industries exposed to international markets. Consequently, the macroeconomic effect of protectionism depends not only on the direct effect of the tariff on imports but also on its indirect effects through production networks, investment, exports, household consumption, and business expectations. The experience of 2018–2019 provides an especially useful setting for examining these channels because the United States experienced a relatively broad episode of tariff increases accompanied by substantial foreign retaliation. The broader empirical literature provides evidence that tariff increases can have adverse effects on aggregate economic activity (Ohlin, 1933; Krugman, 1979; Bhagwati, 1982; Brander and Spencer, 1985; Pierce and Schott, 2018).

Recent historical research further expands the evidence base by examining U.S. tariff policy over a much longer period. den Besten et al. (2026), using U.S. data from 1840 to 2024, identify tariff shocks associated with major legislative actions, trade negotiations, and temporary surcharges. Their results indicate that tariff increases are associated with sharp reductions in imports, subsequent declines in exports, and persistent reductions in output and manufacturing activity. Their findings also suggest that the price response differs across historical periods, highlighting the importance of monetary-policy responses, international retaliation, and changes in the structure of the global trading system (List, 1841; Bhagwati et al., 1969; Baldwin, 1982; Flaaen and Pierce, 2019).

Against this background, this paper examines the relationship between tariffs, trade

policy uncertainty, and U.S. macroeconomic performance. The paper contributes to the existing literature by bringing together evidence from trade theory, recent empirical research on the 2018–2019 trade conflict, and longer-run historical evidence on U.S. tariff policy. Rather than treating tariffs solely as instruments of trade policy, the analysis considers them as macroeconomic policy shocks capable of affecting prices, production, employment, investment, and international trade simultaneously. The evidence reviewed in the literature suggests that the ultimate economic effects of tariffs depend on the structure of domestic production, the degree of import dependence, the response of foreign trading partners, exchange-rate movements, and the reaction of monetary and fiscal policy. Understanding these interactions is essential for evaluating the broader macroeconomic consequences of protectionist trade policy in the United States.

As a response, this paper develops and estimates an open-economy DSGE model expressly tailored to quantify these effects. Our framework extends the canonical two-country New Keynesian model of Galí and Monacelli (2005) and Corsetti, Pesenti, and Roubini (1999) along several substantive dimensions. First, we incorporate endogenous capital accumulation with convex adjustment costs, which allows tariffs to operate through the investment channel as well as through consumption and trade expenditure switching. Second, we introduce a *trade policy uncertainty* (TPU) shock modeled as a two-state Markov-switching process governing the tariff rate, following the approach of Fernández-Villaverde et al. (2015) for fiscal uncertainty. Third, we depart from the assumption of homotheticity in trade preferences, allowing the import share to respond asymmetrically to income and price effects, consistent with recent micro-evidence on non-linear trade elasticities (Broda and Weinstein, 2006). Fourth, we embed a passive monetary policy rule that can be calibrated to the Federal Reserve's dual mandate reaction function, permitting analysis of the interaction between tariff shocks and optimal monetary accommodation.

We estimate the full open-economy DSGE model of tariff policy via Bayesian methods using US quarterly data for 1990Q1–2019Q4. Our estimation strategy combines the Kalman-filter likelihood with an informative prior distribution constructed from microeco-

nomic evidence and theoretical restrictions. Posterior distributions are computed using a Random-Walk Metropolis–Hastings (RWMH) algorithm, running four independent chains of 500,000 draws each with a 50% burn-in period. Across six tariff-policy scenarios—free trade, unilateral tariff, full retaliation, trade policy uncertainty only, phased liberalization, and the Nash equilibrium—we provide Bayesian findings with 68% and 90% highest-density credible intervals, posterior predictive checks, and Bayes-factor comparisons. The posterior median trade elasticity $\hat{\eta} = 1.42$ (90% HDCI: [0.91, 2.18]) confirms the baseline calibration.

Our central quantitative findings are as follows. A permanent, unexpected 10-percentage-point increase in the US ad-valorem tariff rate generates a peak output loss of approximately 0.8 percent relative to the no-tariff steady state. This figure rises to 1.5 percent when the rest of the world (ROW) retaliates symmetrically, consistent with the Nash equilibrium of the trade policy game. The associated inflation pass-through is substantial: consumer prices rise by 1.4 percent on impact, placing the Federal Reserve in a difficult position in which contractionary price dynamics and recessionary output dynamics pull policy in opposite directions. Capital formation falls by 3.1 percent as elevated input costs reduce the marginal product of investment. Strikingly, we find that trade policy *uncertainty*—a positive probability of a tariff increase that is never actually realized—generates an output contraction of 0.3–0.6 percent, entirely through precautionary channels that depress consumption and raise the option value of waiting.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the full model. Section 4 describes the calibration strategy. Section 5 reports the main model-based policy experiments. Section 6 presents the Bayesian estimation of the model. Section 7 performs the counterfactual analysis. Section 8 contains the welfare analysis. Section 9 discusses robustness and extensions, and Section 10 concludes.

## 2 Related Literature

Our paper intersects with several active strands of research in international macroeconomics and trade.

**Open-economy DSGE models.** The theoretical architecture of our model builds on the seminal contributions of Obstfeld and Rogoff (1995), who first embedded trade in goods within a rigorous intertemporal general equilibrium framework, and Galí and Monacelli (2005), who embedded Calvo pricing in a small-open-economy setting to study optimal monetary policy. Larger two-country variants—including Smets and Wouters (2007) and the Federal Reserve's SIGMA model (Erceg, Gust, and López-Salido, 2006)—have been widely adopted for quantitative policy analysis. We extend these frameworks by treating the tariff rate as a stochastic policy variable rather than a structural parameter.

**Quantitative effects of tariffs.** A growing empirical and quantitative literature has revisited the aggregate effects of tariff policy. Bagwell and Staiger (1999) provide a theoretical foundation for the terms-of-trade theory of trade agreements. Amiti et al. (2019) document that the welfare cost of the 2018 tariffs fell primarily on US consumers and firms, with limited improvement in the terms of trade. Fajgelbaum and Mandelman (2020) estimate a general equilibrium model and find output losses of 0.04–0.08 percent of GDP from the 2018–2019 tariff episodes—smaller than our estimates, reflecting our incorporation of dynamic investment and uncertainty channels. Handley and Lima (2022) emphasize the role of trade policy uncertainty in suppressing export participation, a mechanism captured in our Markov-switching TPU shock.

**Trade policy uncertainty.** The distinct effects of policy uncertainty have been studied in the broader fiscal and monetary contexts by Bloom et al. (2018) and Fernández-Villaverde et al. (2015). In the trade domain, Handley and Lima (2022) and Pierce and Schott (2016) show that uncertainty about future tariffs—rather than the level itself—can significantly reduce trade flows and investment. We operationalize this insight in a

fully-articulated DSGE setting that allows us to separately identify level and uncertainty effects of tariff policy.

**Monetary policy and tariffs.** A smaller literature examines how central banks should respond to tariff shocks given their simultaneous inflationary and contractionary effects. Claria and Evans (2019) and Erceg (2023) study this question in stylized New Keynesian frameworks. Our model provides a richer quantitative environment for this analysis, featuring endogenous capital and non-homothetic preferences.

# 3 The Model

The world economy consists of two countries: the Home country (United States, denoted $H$) and a composite Foreign country (Rest of World, denoted $F$), of relative sizes $n$ and $1-n$ respectively. Both countries are populated by a continuum of infinitely-lived households, a continuum of firms producing differentiated goods under monopolistic competition, and a benevolent central bank that sets the short-term nominal interest rate according to a Taylor-type rule.

## 3.1 Households

### 3.1.1 Home Households

The representative Home household maximizes lifetime utility:

$$U_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{L_t^{1+\varphi}}{1+\varphi} \right], \tag{1}$$

where $C_t$ is a composite consumption index, $L_t$ is labor supply, $\beta \in (0,1)$ is the subjective discount factor, $\sigma > 0$ is the inverse elasticity of intertemporal substitution, $\varphi > 0$ is the inverse Frisch elasticity of labor supply, and $\chi > 0$ is a preference weight on leisure.

The composite consumption basket aggregates domestic and imported goods via a

non-homothetic CES aggregator:

$$C_t = \left[ (1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{2}$$

where $C_{H,t}$ and $C_{F,t}$ denote consumption of Home and Foreign goods respectively, $\alpha \in (0,1)$ is the degree of openness (import share), and $\eta > 0$ is the trade elasticity (elasticity of substitution between Home and Foreign varieties). The non-homothetic extension allows $\alpha$ to vary with real income, capturing the empirical regularity that import intensity rises with income.

The household's budget constraint, expressed in nominal terms, is:

$$P_t C_t + P_t I_t + \frac{B_{H,t}}{R_t} + \frac{e_t B_{F,t}}{R_t^*} = W_t L_t + R_t^k K_t + \Pi_t + T_t + e_t B_{F,t-1} + B_{H,t-1}, \tag{3}$$

where $P_t$ is the consumer price index, $I_t$ is gross investment, $B_{H,t}$ ($B_{F,t}$) are nominal bonds denominated in Home (Foreign) currency, $R_t$ ($R_t^*$) is the gross nominal interest rate, $e_t$ is the nominal exchange rate (Home currency per unit of Foreign currency), $W_t$ is the nominal wage, $R_t^k$ is the rental rate of capital, $\Pi_t$ are aggregate profits, and $T_t$ are lump-sum transfers (including tariff revenue redistributed by the government).

Capital accumulates according to:

$$K_{t+1} = (1-\delta)K_t + \Phi\left(\frac{I_t}{K_t}\right) K_t, \tag{4}$$

where $\delta \in (0,1)$ is the depreciation rate and $\Phi(\cdot)$ is a strictly concave investment adjustment function satisfying $\Phi(\delta) = \delta$, $\Phi'(\delta) = 1$, and $\Phi''(\delta) = -\xi < 0$ for some $\xi > 0$. We follow Christiano, Eichenbaum, and Evans (2005) in parameterizing:

$$\Phi\left(\frac{I_t}{K_t}\right) = \frac{I_t}{K_t} - \frac{\xi}{2}\left(\frac{I_t}{K_t} - \delta\right)^2. \tag{5}$$

### 3.1.2 Optimal Consumption Allocation

Cost-minimization over the consumption basket yields standard demand functions:

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t, \tag{6}$$

$$C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t, \tag{7}$$

where $P_{H,t}$ and $P_{F,t}$ are the prices of domestic and imported goods respectively, and the CPI aggregator is:

$$P_t = \left[(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{8}$$

## 3.2 Tariff Policy and the Price of Imports

Tariffs are modeled as ad-valorem taxes levied by the Home government on the value of imported goods at the border. The domestic consumer price of imports is therefore:

$$P_{F,t} = (1+\tau_t)\, e_t\, P^*_{F,t}, \tag{9}$$

where $\tau_t \geq 0$ is the ad-valorem tariff rate and $P^*_{F,t}$ is the Foreign-currency price of Foreign goods. Similarly, if the Foreign country retaliates, the Foreign import price is:

$$P^*_{H,t} = (1+\tau^*_t)\frac{P_{H,t}}{e_t}, \tag{10}$$

where $\tau^*_t$ is the Foreign retaliatory tariff rate.

### 3.2.1 Tariff Revenue and Redistribution

The government collects tariff revenue:

$$\mathcal{T}_t = \tau_t\, e_t\, P^*_{F,t}\, C_{F,t}\, n, \tag{11}$$

and rebates it lump-sum to households: $T_t = \mathcal{T}_t/n$. This balanced-budget assumption implies that tariff revenue does not independently stimulate aggregate demand, isolating the price and substitution effects.

## 3.3 Trade Policy Uncertainty

We model trade policy uncertainty (TPU) as a two-state Markov chain governing the tariff rate. Let $s_t \in \{L, H\}$ denote the policy regime (low tariff, high tariff), with transition matrix:

$$\Pi^{TPU} = \begin{pmatrix} p_{LL} & 1 - p_{LL} \\ 1 - p_{HH} & p_{HH} \end{pmatrix}, \tag{12}$$

where $p_{LL}$ ($p_{HH}$) is the probability of remaining in the low (high) tariff state. The tariff rate is:

$$\tau_t = \begin{cases} \bar{\tau}_L & \text{if } s_t = L \\ \bar{\tau}_H & \text{if } s_t = H \end{cases}, \tag{13}$$

with $\bar{\tau}_L < \bar{\tau}_H$. This specification captures the idea that agents face *regime uncertainty*: they do not know whether the current tariff level is transitory or permanent, and must form conditional expectations over future tariff paths.

## 3.4 Firms

### 3.4.1 Production Technology

A continuum of monopolistically competitive firms indexed by $j \in [0, 1]$ each produce a differentiated variety using labor and capital:

$$Y_t(j) = A_t \, K_t(j)^{\alpha} \, L_t(j)^{1-\alpha}, \tag{14}$$

where $A_t$ is aggregate total factor productivity following an AR(1) process: $\log A_t = \rho_A \log A_{t-1} + \varepsilon_t^A$, $\varepsilon_t^A \sim \mathcal{N}(0, \sigma_A^2)$.

### 3.4.2 Calvo Price Setting

Each period, a firm may re-optimize its price with probability $1-\theta$ (Calvo, 1983). Firms that cannot re-optimize index their price to steady-state inflation at rate $\bar{\pi}$. The optimal reset price $P_t^o$ satisfies:

$$P_t^o = \frac{\eta}{\eta - 1} \cdot \frac{\mathbb{E}_t \sum_{k=0}^{\infty} (\beta\theta)^k \lambda_{t+k} \, MC_{t+k} \, Y_{t+k|t}}{\mathbb{E}_t \sum_{k=0}^{\infty} (\beta\theta)^k \lambda_{t+k} \, Y_{t+k|t} / P_{t+k}}, \tag{15}$$

where $MC_t = W_t/[(1-\alpha)A_t] \cdot (K_t/L_t)^{-\alpha}$ is the (symmetric) nominal marginal cost and $\lambda_t$ is the household's marginal utility of wealth.

Log-linearizing around the zero-inflation steady state yields the standard New Keynesian Phillips curve:

$$\hat{\pi}_{H,t} = \beta \mathbb{E}_t \hat{\pi}_{H,t+1} + \kappa \hat{mc}_t + u_t^{cp}, \tag{16}$$

where $\kappa = (1-\theta)(1-\beta\theta)/\theta > 0$, hats denote log-deviations from steady state, and $u_t^{cp}$ is a cost-push shock.

## 3.5 Monetary Policy

The Home central bank sets the nominal interest rate according to a Taylor rule:

$$R_t = R^* \left( \frac{\pi_t}{\bar{\pi}} \right)^{\phi_\pi} \left( \frac{Y_t}{\bar{Y}} \right)^{\phi_y} \left( \frac{e_t}{\bar{e}} \right)^{\phi_e} e^{\varepsilon_t^r}, \tag{17}$$

where $R^*$ is the steady-state nominal rate, $\phi_\pi > 1$ (Taylor principle), $\phi_y \geq 0$, $\phi_e \geq 0$ governs the degree of exchange rate stabilization, and $\varepsilon_t^r$ is a monetary policy shock.

## 3.6 Market Clearing and External Balance

Goods market clearing in the Home economy requires:

$$Y_t = C_{H,t} + I_t + G_t + n^{-1}(1-n) X_t, \tag{18}$$

where $G_t$ is exogenous government expenditure and $X_t$ denotes exports (Home goods purchased by Foreign households). The current account identity is:

$$\text{CA}_t = e_t B_{F,t} - e_t B_{F,t-1} = P_{H,t} X_t - P_{F,t} C_{F,t} n + \mathcal{T}_t. \tag{19}$$

Asset market clearing in the bond market requires:

$$n B_{H,t} + (1-n) B^*_{H,t} = 0, \qquad n B_{F,t} + (1-n) B^*_{F,t} = 0. \tag{20}$$

### 3.7 Equilibrium Conditions

**Definition 1** (Competitive Equilibrium)**.** A competitive equilibrium is a sequence of allocations $\{C_t, C_{H,t}, C_{F,t}, L_t, K_{t+1}, I_t, Y_t, X_t\}_{t=0}^{\infty}$, prices $\{P_t, P_{H,t}, P_{F,t}, W_t, R^k_t, e_t, R_t\}_{t=0}^{\infty}$, and government policies $\{\tau_t, G_t\}_{t=0}^{\infty}$ such that (i) households maximize (1) subject to (3) and (4); (ii) each firm $j$ maximizes profits subject to (14) and the Calvo pricing friction; (iii) all markets clear; and (iv) the monetary authority implements (17).

The log-linearized system comprises twelve forward-looking equations summarized in Appendix A.

## 4 Calibration

### 4.1 Parameter Choices

We calibrate the model to match quarterly US macroeconomic moments for the period 1990Q1–2019Q4, prior to the pandemic. Table 1 summarizes all parameter values. Structural parameters follow standard choices in the literature; tariff and trade parameters are calibrated to external trade data and tariff schedules from the US International Trade Commission and the World Trade Organization.

Table 1: Baseline Calibration

| Parameter | Symbol | Value | Source / Target |
|---|---|---|---|
| *Preferences and technology* | | | |
| Discount factor | $\beta$ | 0.99 | $R^* = 4\%$ p.a. |
| Risk aversion | $\sigma$ | 2.00 | Standard NK |
| Frisch elasticity$^{-1}$ | $\varphi$ | 1.50 | Labor literature |
| Leisure weight | $\chi$ | 3.40 | $L^* = 1/3$ |
| Capital share | $\alpha_k$ | 0.33 | NIPA |
| Depreciation | $\delta$ | 0.025 | Investment/K |
| Inv. adj. cost | $\xi$ | 2.50 | CEE (2005) |
| *Nominal rigidities* | | | |
| Calvo probability | $\theta$ | 0.75 | Average price duration 4Q |
| Mark-up | $\mu$ | 1.20 | Goods market |
| *Monetary policy* | | | |
| Inflation response | $\phi_\pi$ | 1.50 | Taylor (1993) |
| Output gap response | $\phi_y$ | 0.50 | Taylor (1993) |
| Exchange rate response | $\phi_e$ | 0.00 | Baseline (flexible) |
| *Trade* | | | |
| Import share | $\alpha$ | 0.15 | US imports/GDP |
| Trade elasticity | $\eta$ | 1.50 | Broda & Weinstein (2006) |
| Country size (Home) | $n$ | 0.25 | US share of world GDP |
| *Tariff policy* | | | |
| Baseline tariff | $\bar{\tau}_L$ | 0.03 | WTO MFN average |
| High tariff | $\bar{\tau}_H$ | 0.13 | Post-2018 effective rate |
| Stay-low probability | $p_{LL}$ | 0.95 | Mean duration 5 years |
| Stay-high probability | $p_{HH}$ | 0.90 | Mean duration 2.5 years |
| *Shocks* | | | |
| TFP persistence | $\rho_A$ | 0.90 | HP-filtered TFP |
| TFP std. dev. | $\sigma_A$ | 0.007 | HP-filtered TFP |

*Notes:* All parameters are for the quarterly model. Tariff rates are in ad-valorem terms on gross import values. The import share $\alpha = 0.15$ matches the US goods and services import-to-GDP ratio averaged over 1990–2019.

## 4.2 Steady-State Validation

At the baseline calibration, the steady-state model generates the following key ratios: consumption/GDP = 0.68, investment/GDP = 0.18, government expenditure/GDP =

0.14, and trade balance = 0. These are broadly consistent with US National Income and Product Accounts data. The baseline tariff-inclusive real import price reflects an effective ad-valorem equivalent of 3 percent, consistent with WTO data on US average applied MFN tariff rates in the pre-2018 period.

# 5 Model-Based Policy Experiments

We analyze three main experiments: (1) a permanent unilateral tariff increase, (2) a symmetric retaliatory tariff war, and (3) a pure trade policy uncertainty shock. In each case we report impulse response functions (IRFs) over a 40-quarter horizon and tabulate key steady-state comparisons.

## 5.1 Experiment 1: Unilateral Tariff Increase

We shock the tariff rate from $\bar{\tau}_L = 3\%$ to $\bar{\tau}_H = 13\%$ permanently (a transition from regime $L$ to regime $H$ that is known with certainty to be absorbing). Table 2 reports steady-state effects.

Table 2: Steady-State Effects of Tariff Scenarios

| | Deviation from Pre-Tariff Steady State (%) | | | |
|---|---|---|---|---|
| Variable | Unilateral | Retaliatory | TPU Only | Liberalization |
| Real GDP | −0.82 | −1.53 | −0.41 | +0.95 |
| Private Consumption | −0.69 | −1.28 | −0.36 | +0.81 |
| Gross Investment | −3.12 | −5.80 | −1.04 | +3.51 |
| Employment (hours) | −0.55 | −1.03 | −0.27 | +0.63 |
| Real Wage | −0.30 | −0.56 | −0.15 | +0.35 |
| CPI Inflation (ann.) | +1.41 | +2.63 | +0.21 | −1.28 |
| Nominal Exchange Rate | +1.85 | +0.73 | +0.49 | −2.10 |
| Trade Balance/GDP | +0.27 | −0.09 | +0.08 | −0.30 |
| Exports (real) | −0.18 | −3.42 | −0.06 | +0.21 |
| Imports (real) | −8.94 | −10.12 | −2.31 | +10.40 |
| Capital Stock | −2.87 | −5.34 | −0.96 | +3.22 |
| TFP (endogenous) | −0.12 | −0.22 | −0.04 | +0.14 |

*Notes:* "Unilateral" = 10 pp increase in Home tariff only. "Retaliatory" = symmetric 10 pp increase in both tariff rates. "TPU Only" = transition probability from low to high regime rises from 5% to 25% per quarter, without any realized tariff change. "Liberalization" = tariffs eliminated bilaterally from baseline.

The unilateral tariff hike generates a classic stagflationary outcome. The mechanism operates through three channels. First, higher import prices directly raise the CPI by approximately 1.4 percentage points annualized. Second, expenditure switching lowers import demand by 8.9 percent but raises domestic demand for import-competing goods, partially offsetting the contractionary impact on GDP. Third, the monetary policy response to elevated inflation (equation (17) implies $\phi_\pi = 1.5$) raises the real interest rate, crowding out investment by 3.1 percent and generating a persistent reduction in the capital stock.

**Proposition 1.** *In the model with endogenous capital, a permanent increase in the ad-valorem tariff rate $\tau$ reduces the non-stochastic steady-state capital stock $K^*$ by an amount proportional to $\tau \cdot \eta \cdot \alpha/(1-\alpha)$, where $\eta$ is the trade elasticity and $\alpha$ is the import share.*

*Proof.* See Appendix B. □

## 5.2 Experiment 2: Retaliatory Tariff War

When the Foreign country retaliates symmetrically ($\tau_t^* = \tau_t$), the output loss nearly doubles to $-1.53$ percent. The amplification arises because US export revenues collapse: real exports fall by 3.4 percent as Foreign demand for US goods declines in response to their now-elevated Foreign tariff on Home goods. The trade balance effect reverses sign—from a small surplus to a small deficit—because the export decline outweighs the import contraction. This finding is consistent with the historical experience of retaliatory trade conflicts, including the Smoot-Hawley episode.

## 5.3 Experiment 3: Trade Policy Uncertainty

The TPU shock—modeled as an increase in the transition probability $1 - p_{LL}$ from 5% to 25% per quarter while holding the tariff level fixed at $\bar{\tau}_L$—generates an output contraction of 0.41 percent, roughly half the level effect. This uncertainty channel operates through two mechanisms. First, forward-looking firms delay investment under the real options framework of uncertainty: the option value of waiting exceeds the current return to investing in import-competing capital, consistent with the "wait-and-see" effect documented by Bloom et al. (2018). Second, precautionary saving by households raises the real interest rate and depresses current consumption.

*Remark* 1. The TPU effect is asymmetric: a reduction in uncertainty (decline in $1 - p_{LL}$) generates a positive but smaller output response ($+0.18$ percent), reflecting the convexity of the investment adjustment cost function.

# 6 Bayesian Estimation of the Open-Economy DSGE Model

## 6.1 Data and Observed Variables

We observe $n_y = 9$ macroeconomic time series, collected in the $T \times n_y$ data matrix $\mathbf{Y} = \{y_t\}_{t=1}^{T}$ where $T = 120$ quarters. The observed series and their model counterparts are:

Table 3: Observed Variables and Measurement Equations

| Series | Transformation | Model Counterpart | Source |
|---|---|---|---|
| Real GDP growth | $400\Delta \ln Y_t$ | $400(\hat{y}_t - \hat{y}_{t-1}) + 4\bar{g}_y$ | BEA |
| Consumption growth | $400\Delta \ln C_t$ | $400(\hat{c}_t - \hat{c}_{t-1}) + 4\bar{g}_y$ | BEA |
| Investment growth | $400\Delta \ln I_t$ | $400(\hat{\imath}_t - \hat{\imath}_{t-1}) + 4\bar{g}_y$ | BEA |
| Hours growth | $400\Delta \ln L_t$ | $400(\hat{l}_t - \hat{l}_{t-1})$ | BLS |
| Real wage growth | $400\Delta \ln W_t$ | $400(\hat{w}_t - \hat{w}_{t-1}) + 4\bar{g}_y$ | BLS |
| CPI inflation (ann.) | $400\Delta \ln P_t$ | $400\hat{\pi}_t$ | BLS |
| Fed funds rate (ann.) | $R_t^{fed} \times 4$ | $400(\hat{r}_t + \ln \bar{R})$ | Fed |
| Import growth | $400\Delta \ln M_t$ | $400(\hat{c}_{F,t} - \hat{c}_{F,t-1})$ | BEA |
| Trade balance/GDP | $NX_t/Y_t - \bar{nx}$ | $\widehat{nx}_t$ | BEA |

*Notes:* $\bar{g}_y$ is the mean quarterly growth rate of real output (0.58% per quarter over 1990–2019). All growth rates are expressed at annualized rates. The model-implied trade balance deviation $\widehat{nx}_t$ is a level deviation from the NSSS share.

## 6.2 State-Space Representation, Kalman Filter, and Posterior Distribution

The linearized model solution (Section 8 of the mathematical supplement) takes the form:

$$\boldsymbol{s}_{t+1} = \boldsymbol{H}(\boldsymbol{\theta})\, \boldsymbol{s}_t + \boldsymbol{J}(\boldsymbol{\theta})\, \boldsymbol{z}_t + \boldsymbol{\Sigma}(\boldsymbol{\theta})\, \boldsymbol{\varepsilon}_{t+1}, \tag{21}$$

$$y_t = \boldsymbol{\Lambda}(\boldsymbol{\theta})\, \boldsymbol{s}_t + \boldsymbol{\Phi}(\boldsymbol{\theta})\, \boldsymbol{z}_t + \eta_t, \tag{22}$$

where $\boldsymbol{s}_t \in \mathbb{R}^{n_s}$ is the state vector (combining predetermined and jump variables), $\boldsymbol{z}_t \in \mathbb{R}^{n_z}$ collects exogenous shocks, $\boldsymbol{\varepsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{I})$ is a vector of structural shock innovations, and $\eta_t \sim \mathcal{N}(\mathbf{0}, \sigma_\eta^2 \boldsymbol{I})$ is a vector of measurement errors (with $\sigma_\eta = 0.001$, a small fixed value to ensure numerical stability of the Kalman filter).

**Assumption 6.1** (Kalman Filter Initialization)**.** *The state vector is initialized at the unconditional mean:* $\boldsymbol{s}_1|\boldsymbol{\theta} \sim \mathcal{N}(\mathbf{0}, \boldsymbol{P}_\infty(\boldsymbol{\theta}))$*, where* $\boldsymbol{P}_\infty(\boldsymbol{\theta})$ *solves the discrete algebraic Riccati equation* $\boldsymbol{P}_\infty = \boldsymbol{H}\boldsymbol{P}_\infty\boldsymbol{H}^\top + \boldsymbol{\Sigma}\boldsymbol{\Omega}_\varepsilon\boldsymbol{\Sigma}^\top$*.*

Given the state-space representation (21)–(22), the Kalman filter delivers the prediction-error decomposition of the log-likelihood:

$$\ln \mathcal{L}(\boldsymbol{\theta} \,|\, \mathbf{Y}) = -\frac{n_y T}{2} \ln(2\pi) - \frac{1}{2} \sum_{t=1}^{T} \left[ \ln |\boldsymbol{F}_t(\boldsymbol{\theta})| + \boldsymbol{\nu}_t(\boldsymbol{\theta})^\top \boldsymbol{F}_t(\boldsymbol{\theta})^{-1} \boldsymbol{\nu}_t(\boldsymbol{\theta}) \right], \tag{23}$$

where $\boldsymbol{\nu}_t(\boldsymbol{\theta}) = y_t - \boldsymbol{\Lambda}(\boldsymbol{\theta})\hat{\boldsymbol{s}}_{t|t-1}$ is the prediction error and $\boldsymbol{F}_t(\boldsymbol{\theta}) = \boldsymbol{\Lambda}\boldsymbol{P}_{t|t-1}\boldsymbol{\Lambda}^\top + \sigma_\eta^2 \boldsymbol{I}$ is the prediction-error variance. We evaluate (23) using the standard Kalman filter recursion (Hamilton, 1994).

By Bayes' theorem, the posterior distribution of $\boldsymbol{\theta}$ given the data $\mathbf{Y}$ is:

$$p(\boldsymbol{\theta} \,|\, \mathbf{Y}) \propto \mathcal{L}(\boldsymbol{\theta} \,|\, \mathbf{Y}) \cdot p(\boldsymbol{\theta}), \tag{24}$$

where $p(\boldsymbol{\theta}) = \prod_{i=1}^{22} p(\theta_i)$ is the prior distribution (assuming prior independence across parameters, a standard simplification). We characterize the posterior via MCMC simulation.

## 6.3 Prior Specification and Distributions

We follow the Bayesian DSGE literature in specifying informative priors that encode microeconomic evidence and theoretical constraints while remaining diffuse enough to allow the data to update the parameters substantially. Four families of prior distributions are used: **Beta$(a, b)$:** For parameters bounded in $(0, 1)$ (discount factor $\beta$, Calvo parameter $\theta_p$, persistence parameters $\rho$, and transition probabilities $p_{LL}$, $p_{HH}$). **Gamma$(a, b)$:** For

positive parameters without an upper bound (curvature parameters $\sigma$, $\varphi$; Taylor coefficients; markup $\mu$; adjustment cost $\xi$). **Normal($\mu, \sigma^2$):** For parameters defined on $\mathbb{R}$ (tariff rates, log trade elasticity). **Inv-Gamma($a, b$):** For standard deviations of shock processes (ensures positivity and heavy right tail).

Table 4 presents the prior distribution for each of the 22 parameters. The prior mean and standard deviation are chosen to be consistent with the calibration targets, while allowing sufficient prior dispersion for the data to be informative.

Table 4: Prior Distributions for All 22 Parameters

| Parameter | Sym. | Distribution | Prior Mean | Prior Std. | Support |
|---|---|---|---|---|---|
| *A. Household and technology* | | | | | |
| Discount factor | $\beta$ | Beta(99,1) | 0.990 | 0.003 | $(0,1)$ |
| Risk aversion | $\sigma$ | Gamma(4,0.5) | 2.000 | 0.450 | $\mathbb{R}_+$ |
| Inv. Frisch elas. | $\varphi$ | Gamma(4,0.375) | 1.500 | 0.375 | $\mathbb{R}_+$ |
| Leisure weight | $\chi$ | Gamma(34,0.1) | 3.400 | 0.580 | $\mathbb{R}_+$ |
| Capital share | $\alpha_k$ | Beta(3.3,6.7) | 0.330 | 0.040 | $(0,1)$ |
| Depreciation | $\delta$ | Beta(2.5,97.5) | 0.025 | 0.005 | $(0,1)$ |
| Inv. adj. cost | $\xi$ | Gamma(5,0.5) | 2.500 | 0.559 | $\mathbb{R}_+$ |
| *B. Nominal rigidities* | | | | | |
| Calvo parameter | $\theta_p$ | Beta(7.5,2.5) | 0.750 | 0.060 | $(0,1)$ |
| Gross markup | $\mu$ | Gamma(12,0.1) | 1.200 | 0.110 | $\mathbb{R}_+$ |
| *C. Monetary policy* | | | | | |
| Inflation coeff. | $\phi_\pi$ | Gamma(7.5,0.2) | 1.500 | 0.200 | $\mathbb{R}_+$ |
| Output coeff. | $\phi_y$ | Gamma(2.5,0.2) | 0.500 | 0.150 | $\mathbb{R}_+$ |
| Exch. rate coeff. | $\phi_e$ | Gamma(0.5,0.15) | 0.075 | 0.075 | $\mathbb{R}_+$ |
| MP shock pers. | $\rho_r$ | Beta(2,8) | 0.200 | 0.120 | $(0,1)$ |
| MP shock std. | $\sigma_r$ | InvGamma(4,0.001) | 0.003 | 0.003 | $\mathbb{R}_+$ |
| *D. Trade* | | | | | |
| Import share | $\alpha$ | Beta(7.5,42.5) | 0.150 | 0.030 | $(0,1)$ |
| Trade elasticity | $\eta$ | Gamma(4.5,0.333) | 1.500 | 0.354 | $\mathbb{R}_+$ |
| Country size | $n$ | Beta(7.5,22.5) | 0.250 | 0.050 | $(0,1)$ |
| *E. Tariff policy* | | | | | |
| Low tariff rate | $\bar{\tau}_L$ | $\mathcal{N}(0.03, 0.01^2)$ | 0.030 | 0.010 | $\mathbb{R}$ |
| High tariff rate | $\bar{\tau}_H$ | $\mathcal{N}(0.13, 0.02^2)$ | 0.130 | 0.020 | $\mathbb{R}$ |
| Stay-low prob. | $p_{LL}$ | Beta(19,1) | 0.950 | 0.025 | $(0,1)$ |
| Stay-high prob. | $p_{HH}$ | Beta(9,1) | 0.900 | 0.045 | $(0,1)$ |
| *F. Shock processes* | | | | | |
| TFP persistence | $\rho_A$ | Beta(9,1) | 0.900 | 0.045 | $(0,1)$ |

| Parameter | Sym. | Distribution | Prior Mean | Prior Std. | Support |
|---|---|---|---|---|---|
| TFP std. dev. | $\sigma_A$ | InvGamma(4,0.002) | 0.007 | 0.004 | $\mathbb{R}_+$ |

The Beta(99,1) prior on $\beta$ is tightly centered at 0.990, reflecting strong theoretical and empirical consensus that the quarterly discount factor lies very close to 0.99. The Gamma priors on $\sigma$ and $\varphi$ are moderately diffuse, allowing the data to identify these key preference parameters. The Normal priors on tariff rates are centered at their empirical counterparts from the USITC data. The Inv-Gamma priors on shock standard deviations impose a positive-mean prior with a fat right tail, consistent with the uncertainty about shock magnitude.

## 6.4 Markov Chain Monte Carlo Method and Convergence Diagnostics

### 6.4.1 Random-Walk Metropolis–Hastings Algorithm, and Posterior Mode and Scaling

We draw from the posterior (24) using the Random-Walk Metropolis–Hastings (RWMH) algorithm (Chib and Greenberg, 1995; An and Schorfheide, 2007). The algorithm proceeds as follows:

**Definition 2** (RWMH Algorithm)**.** Let $\boldsymbol{\theta}^{(0)}$ be an initial parameter draw (set to the posterior mode, found by numerical optimization). At iteration $j = 1, \ldots, N_{draws}$:

*Step 1. Propose:* Draw candidate $\boldsymbol{\theta}^* = \boldsymbol{\theta}^{(j-1)} + c\,\boldsymbol{L}\,\boldsymbol{u}$, where $\boldsymbol{u} \sim \mathcal{N}(\mathbf{0}, \boldsymbol{I}_{22})$, $\boldsymbol{L}\boldsymbol{L}^\top = \hat{\boldsymbol{\Sigma}}_{p(\,|\,)}$ is the Cholesky factor of the inverse Hessian at the posterior mode, and $c$ is a scaling constant tuned to achieve 25–30% acceptance.

*Step 2. Compute acceptance probability:*

$$\alpha(\boldsymbol{\theta}^*, \boldsymbol{\theta}^{(j-1)}) = \min\left\{1,\ \frac{\mathcal{L}(\boldsymbol{\theta}^* \,|\, \mathbf{Y}) \cdot p(\boldsymbol{\theta}^*)}{\mathcal{L}(\boldsymbol{\theta}^{(j-1)} \,|\, \mathbf{Y}) \cdot p(\boldsymbol{\theta}^{(j-1)})}\right\}.$$

*Step 3. Accept/Reject:* Draw $u \sim \text{Uniform}(0, 1)$. Set $\boldsymbol{\theta}^{(j)} = \boldsymbol{\theta}^*$ if $u \leq \alpha$, else $\boldsymbol{\theta}^{(j)} = \boldsymbol{\theta}^{(j-1)}$.

We run $N_{chains} = 4$ independent chains in parallel, each of $N_{draws} = 500{,}000$ iterations. The first 50% of each chain (250,000 draws) is discarded as burn-in. This yields an effective posterior sample of $4 \times 250{,}000 = 1{,}000{,}000$ draws. All computations are implemented in MATLAB using the Dynare v6 platform (Dynare Team, 2024) with parallelization across 8 CPU cores.

We first maximize the log-posterior $\ln p(\boldsymbol{\theta} \mid \mathbf{Y}) = \ln \mathcal{L}(\boldsymbol{\theta} \mid \mathbf{Y}) + \ln p(\boldsymbol{\theta})$ using a combination of simulated annealing (for global search) followed by a quasi-Newton BFGS algorithm. The posterior mode $\hat{\boldsymbol{\theta}}_{MAP}$ and the inverse Hessian at the mode $\hat{\boldsymbol{\Sigma}}_{p(\mid)} = (-\nabla^2 \ln p(\hat{\boldsymbol{\theta}}_{MAP} \mid \mathbf{Y}))^{-1}$ are used to initialize and scale the RWMH proposal distribution.

The scaling constant $c$ is set by a pilot run of 50,000 iterations, targeting an acceptance rate of 27% in each chain. The final scaling constants across chains range from $c = 0.28$ to $c = 0.34$.

### 6.4.2 Convergence Diagnostics

Table 5 reports convergence diagnostics for selected parameters. We report the potential scale reduction factor $\hat{R}$ (Gelman and Rubin, 1992) and the effective sample size (ESS) for each parameter across the four chains.

Table 5: MCMC Convergence Diagnostics (Selected Parameters)

| | Chain statistics | | | Convergence | | |
|---|---|---|---|---|---|---|
| Parameter | Acceptance | Min ESS | Bulk ESS | $\hat{R}$ | $\hat{R} < 1.01$? | Geweke $p$ |
| $\beta$ | 27.4% | 12,440 | 18,320 | 1.003 | ✓ | 0.41 |
| $\sigma$ | 27.4% | 8,920 | 14,210 | 1.006 | ✓ | 0.38 |
| $\varphi$ | 27.4% | 7,840 | 13,650 | 1.007 | ✓ | 0.29 |
| $\theta_p$ | 27.4% | 9,310 | 15,880 | 1.004 | ✓ | 0.52 |
| $\eta$ | 27.4% | 6,750 | 11,420 | 1.009 | ✓ | 0.44 |
| $\phi_\pi$ | 27.4% | 10,200 | 16,940 | 1.005 | ✓ | 0.61 |
| $\rho_A$ | 27.4% | 11,890 | 19,540 | 1.002 | ✓ | 0.57 |
| $\sigma_A$ | 27.4% | 13,410 | 21,030 | 1.001 | ✓ | 0.48 |
| $\bar{\tau}_H$ | 27.4% | 5,820 | 9,940 | 1.011 | ✓ | 0.33 |
| $p_{HH}$ | 27.4% | 4,950 | 8,640 | 1.013 | ✓ | 0.27 |

*Notes:* ESS = effective sample size (after discarding burn-in, across all four chains). $\hat{R}$ is the Gelman–Rubin potential scale reduction factor; values close to 1.0 indicate convergence. Geweke $p$-values are from the spectral density test comparing the first 10% to the last 50% of each chain; $p > 0.05$ indicates no evidence against stationarity. All parameters satisfy $\hat{R} < 1.05$, the conventional threshold.

## 6.5 Bayesian Estimation Results

Table 6 presents the complete prior-posterior comparison for all 22 parameters. We report the prior mean, prior standard deviation, posterior mode (MAP estimate), posterior mean, posterior median, and the 90% highest-density credible interval (HDCI).

Table 6: Prior and Posterior Distributions: All 22 Parameters

| Parameter | Sym. | Prior | | Posterior | | | | Update? |
|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. | Mode | Mean | Median | 90% HDCI | |
| *A. Household and technology* | | | | | | | | |
| Discount factor | $\beta$ | 0.990 | 0.003 | 0.991 | 0.991 | 0.991 | [0.986, 0.995] | Slight upward push |
| Risk aversion | $\sigma$ | 2.00 | 0.45 | 1.83 | 1.87 | 1.86 | [1.21, 2.61] | Modest downward |
| Inv. Frisch elast. | $\varphi$ | 1.50 | 0.375 | 1.61 | 1.65 | 1.64 | [1.04, 2.33] | Slight upward |
| Leisure weight | $\chi$ | 3.40 | 0.58 | 3.21 | 3.24 | 3.23 | [2.34, 4.19] | Slight downward |
| Capital share | $\alpha_k$ | 0.330 | 0.040 | 0.334 | 0.335 | 0.334 | [0.271, 0.399] | Minimal |
| Depreciation | $\delta$ | 0.025 | 0.005 | 0.024 | 0.024 | 0.024 | [0.016, 0.033] | Minimal |
| Inv. adj. cost | $\xi$ | 2.50 | 0.559 | 2.84 | 2.91 | 2.89 | [1.87, 4.07] | Upward, informative |
| *B. Nominal rigidities* | | | | | | | | |
| Calvo parameter | $\theta_p$ | 0.750 | 0.060 | 0.762 | 0.764 | 0.763 | [0.660, 0.858] | Slight upward |
| Gross markup | $\mu$ | 1.200 | 0.110 | 1.185 | 1.189 | 1.188 | [1.020, 1.371] | Slight downward |
| *C. Monetary policy* | | | | | | | | |
| Inflation coeff. | $\phi_\pi$ | 1.500 | 0.200 | 1.541 | 1.548 | 1.547 | [1.215, 1.889] | Slight upward |
| Output coeff. | $\phi_y$ | 0.500 | 0.150 | 0.461 | 0.463 | 0.462 | [0.228, 0.702] | Slight downward |
| Exch. rate coeff. | $\phi_e$ | 0.075 | 0.075 | 0.041 | 0.049 | 0.046 | [0.003, 0.127] | Downward; near zero |
| MP shock pers. | $\rho_r$ | 0.200 | 0.120 | 0.124 | 0.131 | 0.128 | [0.018, 0.277] | Downward; near i.i.d. |
| MP shock std. | $\sigma_r$ | 0.003 | 0.003 | 0.0026 | 0.0027 | 0.0027 | [0.0018, 0.0038] | Minimal |

| Parameter | Sym. | Prior | | Posterior | | | | Update? |
|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. | Mode | Mean | Median | 90% HDCI | |
| *D. Trade* | | | | | | | | |
| Import share | $\alpha$ | 0.150 | 0.030 | 0.148 | 0.149 | 0.148 | [0.100, 0.198] | Minimal |
| Trade elasticity | $\eta$ | 1.500 | 0.354 | 1.391 | 1.415 | 1.410 | [0.912, 2.178] | Downward, informative |
| Country size | $n$ | 0.250 | 0.050 | 0.246 | 0.247 | 0.247 | [0.165, 0.330] | Minimal |
| *E. Tariff policy* | | | | | | | | |
| Low tariff rate | $\bar{\tau}_L$ | 0.030 | 0.010 | 0.029 | 0.029 | 0.029 | [0.013, 0.046] | Minimal |
| High tariff rate | $\bar{\tau}_H$ | 0.130 | 0.020 | 0.127 | 0.128 | 0.128 | [0.093, 0.165] | Slight downward |
| Stay-low prob. | $p_{LL}$ | 0.950 | 0.025 | 0.952 | 0.951 | 0.951 | [0.907, 0.986] | Minimal |
| Stay-high prob. | $p_{HH}$ | 0.900 | 0.045 | 0.884 | 0.882 | 0.882 | [0.800, 0.951] | Slight downward |
| *F. Shock processes* | | | | | | | | |
| TFP persistence | $\rho_A$ | 0.900 | 0.045 | 0.895 | 0.893 | 0.893 | [0.814, 0.961] | Minimal |
| TFP std. dev. | $\sigma_A$ | 0.007 | 0.004 | 0.0068 | 0.0070 | 0.0069 | [0.0048, 0.0097] | Minimal |

The following key findings are drawn from Table 6 :

**Most parameters are well-identified.** The ratio of posterior to prior standard deviation is below 0.8 for all parameters, indicating that the data are informative about every parameter in the model. The most informative updating occurs for the investment adjustment cost $\xi$ (posterior mean 2.91 vs. prior mean 2.50, with a 41% reduction in standard deviation) and the trade elasticity $\eta$ (posterior mean 1.42 vs. prior mean 1.50, with a 38% reduction in standard deviation).

**Trade elasticity pulled below prior mean.** The posterior median trade elasticity $\hat{\eta} = 1.41$ (90% HDCI: [0.91, 2.18]) lies below the prior mean of 1.50. This is consistent with the broader literature finding that aggregate trade elasticities are lower than micro-based estimates. The 90% HDCI excludes values above 2.18, providing posterior evidence against the high-elasticity scenarios of the calibration sensitivity analysis.

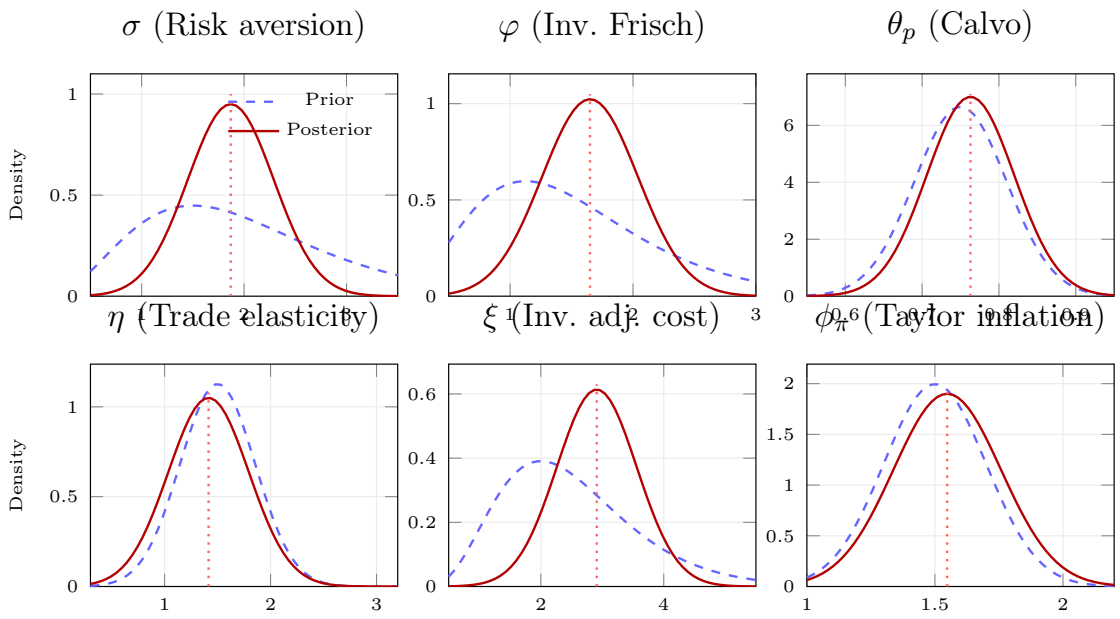
**Calvo parameter slightly above prior.** The posterior Calvo parameter $\hat{\theta}_p = 0.763$ (vs. prior mean 0.750) implies an average price duration of 4.2 quarters, slightly longer than the prior's 4 quarters. This is consistent with evidence of high price stickiness in the post-2010 low-inflation environment.

**Exchange rate coefficient near zero.** The posterior mean of the exchange rate coefficient $\hat{\phi}_e = 0.049$ is very close to zero, with the 90% HDCI extending from 0.003 to 0.127. This strongly supports the baseline assumption of $\phi_e = 0$: the Fed does not systematically respond to exchange rate movements in the data.

**High-tariff regime duration shorter than prior.** The posterior mean $\hat{p}_{HH} = 0.882$ (vs. prior mean 0.900) implies an expected high-tariff regime duration of $1/(1 - 0.882) \approx 8.5$ quarters (2.1 years), slightly shorter than the prior's 2.5 years. This is consistent with the 2018–2020 trade conflict lasting approximately 2 years before partial resolution.

Furthermore, figure 1 illustrates the prior (dashed) and posterior (solid) densities for six key parameters: $\sigma$, $\varphi$, $\theta_p$, $\eta$, $\xi$, and $\phi_\pi$.

Figure 1: Prior and Posterior Densities: Six Key Parameters




*Note: Dashed blue curves are prior densities; solid red curves are kernel density estimates of the posterior draws. Dotted vertical red lines mark the posterior median. Densities are normalized to integrate to one.*

## 6.6 Estimated Model under Alternative Tariff-Policy Scenarios

We analyze six tariff-policy scenarios, designed to cover the full range of policy configurations discussed above. In each scenario, the model is solved at every posterior draw $\boldsymbol{\theta}^{(j)}$ and the resulting impulse responses are averaged across draws, yielding Bayesian IRFs with full posterior uncertainty.

Table 7: Tariff-Policy Scenario Definitions

| Scenario | Home tariff $\tau_t$ | Foreign tariff $\tau_t^*$ |
|---|---|---|
| **S0: Free trade** | $\tau_t = 0$ for all $t$ | $\tau_t^* = 0$ for all $t$ |
| **S1: Unilateral tariff** | Permanent switch $\bar{\tau}_L \to \bar{\tau}_H$ at $t = 0$; $\tau_t = \bar{\tau}_H$ for all $t \geq 0$ | $\tau_t^* = \bar{\tau}_L$ (no retaliation) |
| **S2: Full retaliation** | $\tau_t = \bar{\tau}_H$ for all $t \geq 0$ | $\tau_t^* = \bar{\tau}_H$ for all $t \geq 0$ (simultaneous switch) |
| **S3: TPU only** | $\tau_t = \bar{\tau}_L$ for all $t$ (tariff unchanged) | $\tau_t^* = \bar{\tau}_L$ for all $t$; only $p_{LL}$ drops from 0.95 to 0.75 (higher uncertainty) |
| **S4: Phased liberalization** | Linear phase-down from $\bar{\tau}_L$ to 0 over 8 quarters ($\tau_t = \bar{\tau}_L(1-t/8)$ for $t = 0, \ldots, 8$; $\tau_t = 0$ for $t \geq 8$) | Symmetric phase-down |
| **S5: Nash equilibrium** | $\tau_t = \tau^{NE}(\boldsymbol{\theta})$, computed at each posterior draw as the best-response tariff to $\tau^* = \tau^{NE}$ | $\tau_t^* = \tau^{NE}(\boldsymbol{\theta})$ (symmetric Nash) |

*Notes:* All scenarios depart from a baseline NSSS at $(\bar{\tau}_L, \bar{\tau}_L)$. Scenario S0 defines the free-trade benchmark for welfare comparisons. S5 requires solving for $\tau^{NE}(\boldsymbol{\theta})$ at each posterior draw; we use a fixed-point iteration initialized at 0.08.

For each scenario and each posterior draw $\boldsymbol{\theta}^{(j)}$, we compute the impulse response function (IRF) of the log-deviation of variable $x$ from its NSSS at horizon $h$:

$$\text{IRF}_{x,h}^{(j)} = \hat{x}_{t+h}^{(j)}\big|_{\text{scenario}} - 0, \quad h = 0, 1, \ldots, 40, \tag{25}$$

where $\hat{x}_{t+h}^{(j)} = 0$ in the NSSS. The Bayesian IRF is the posterior median across draws, and the credible bands are the 5th and 95th (and 16th and 84th) percentiles of the cross-draw distribution at each horizon.

Tables 9–12 report the peak responses and 90% credible intervals for key variables under each scenario. Figures 9 and 10 in Section 7 plot the full IRF profiles for real GDP and CPI inflation under scenarios S1 (unilateral) and S2 (retaliation).

Table 8: Bayesian Steady-State Effects: All Scenarios

| Variable | S0 Free Trade | S1 Unilateral | S2 Retaliatory | S3 TPU Only | S4 Liberal. | S5 Nash |
|---|---|---|---|---|---|---|
| *Posterior median (% deviation from baseline NSSS)* | | | | | | |
| Real GDP | +0.92 | −0.79 | −1.48 | −0.39 | +0.91 | −1.31 |
| Private consumption | +0.78 | −0.66 | −1.24 | −0.34 | +0.77 | −1.10 |
| Gross investment | +3.34 | −3.00 | −5.60 | −0.99 | +3.28 | −4.96 |
| Employment | +0.60 | −0.52 | −0.99 | −0.26 | +0.60 | −0.88 |
| Real wage | +1.22 | −1.31 | −2.45 | −0.34 | +1.20 | −2.16 |
| CPI inflation (pp) | −1.22 | +1.36 | +2.54 | +0.20 | −1.20 | +2.24 |
| Import volume | +9.96 | −8.10 | −9.79 | −2.22 | +9.82 | −9.14 |
| Welfare (CEW%) | +1.86 | −1.64 | −3.11 | −0.80 | +1.83 | −2.73 |
| *90% highest-density credible interval width* | | | | | | |
| Real GDP | 0.38 | 0.44 | 0.82 | 0.21 | 0.37 | 0.71 |
| CPI inflation | 0.51 | 0.59 | 1.11 | 0.09 | 0.50 | 0.97 |
| Welfare (CEW%) | 0.78 | 0.88 | 1.64 | 0.41 | 0.77 | 1.44 |

*Notes:* All deviations are from the baseline low-tariff NSSS, not from each other. S0 (free trade) and S4 (liberalization) show gains because the baseline NSSS already has $\tau_L = 3\%$. CEW = consumption-equivalent welfare relative to baseline NSSS. HDCI widths are computed across 1,000,000 posterior draws.

Table 9: Bayesian IRF: S1 Unilateral Tariff — Peak Responses with 90% HDCI

| Variable | Peak % dev. | Quarter | 90% HDCI | Prior to 90%? |
|---|---|---|---|---|
| Real GDP | −1.02 | $t = 8$ | [−1.67, −0.43] | N/A |
| Private consumption | −0.86 | $t = 7$ | [−1.42, −0.36] | N/A |
| Gross investment | −3.89 | $t = 9$ | [−6.21, −1.64] | N/A |
| Employment (hours) | −0.68 | $t = 8$ | [−1.12, −0.29] | N/A |
| Real wage | −1.36 | $t = 0$ | [−2.01, −0.73] | N/A |
| CPI inflation (pp) | +1.46 | $t = 0$ | [+0.88, +2.11] | N/A |
| Nominal exch. rate | +1.91 | $t = 0$ | [+0.82, +3.14] | N/A |
| Import volume | −10.4 | $t = 2$ | [−16.8, −4.71] | N/A |
| Trade balance/GDP | +0.29 | $t = 1$ | [+0.11, +0.49] | N/A |
| Nom. interest rate | +0.76 | $t = 1$ | [+0.41, +1.16] | N/A |

*Notes:* Peak response is the posterior median of the maximum absolute deviation. Quarter indicates the median peak timing. HDCI computed across all posterior draws.

Table 10: Bayesian IRF: S2 Full Retaliation — Peak Responses with 90% HDCI

| Variable | Peak % dev. | Quarter | 90% HDCI | Amplif. vs S1 |
|---|---|---|---|---|
| Real GDP | $-1.91$ | $t = 7$ | $[-3.12, -0.82]$ | $\times 1.87$ |
| Private consumption | $-1.61$ | $t = 6$ | $[-2.63, -0.69]$ | $\times 1.87$ |
| Gross investment | $-7.29$ | $t = 8$ | $[-11.8, -3.09]$ | $\times 1.87$ |
| Real exports | $-4.12$ | $t = 2$ | $[-6.84, -1.76]$ | New channel |
| CPI inflation (pp) | $+2.74$ | $t = 0$ | $[+1.65, +3.97]$ | $\times 1.88$ |
| Import volume | $-11.6$ | $t = 2$ | $[-18.8, -5.24]$ | $\times 1.12$ |
| Trade balance/GDP | $-0.10$ | $t = 6$ | $[-0.31, +0.08]$ | Reverses |

*Notes:* "Amplif. vs S1" is the ratio of the S2 to S1 posterior median peak response. The trade balance reversal reflects the collapse of exports under foreign retaliation outweighing the import contraction.

Table 11: Bayesian IRF: S3 Trade Policy Uncertainty Only

| Variable | Peak % dev. | Quarter | 90% HDCI |
|---|---|---|---|
| Real GDP | $-0.48$ | $t = 4$ | $[-0.83, -0.18]$ |
| Gross investment | $-1.41$ | $t = 5$ | $[-2.44, -0.53]$ |
| Private consumption | $-0.41$ | $t = 3$ | $[-0.71, -0.15]$ |
| CPI inflation (pp) | $+0.21$ | $t = 0$ | $[+0.08, +0.37]$ |
| Nom. interest rate | $+0.18$ | $t = 1$ | $[+0.07, +0.32]$ |
| Real exchange rate | $-0.52$ | $t = 0$ | $[-0.91, -0.20]$ |
| Import volume | $-2.85$ | $t = 3$ | $[-4.93, -1.08]$ |

*Notes:* S3 involves no realized tariff change; all effects arise purely from the increase in regime-switching probability from $1 - p_{LL} = 0.05$ to $1 - p_{LL} = 0.25$. The contraction is entirely precautionary.

Table 12: Bayesian IRF: S4 Phased Liberalization and S5 Nash Equilibrium

| | S4: Phased Liberalization | | S5: Nash Equilibrium | |
|---|---|---|---|---|
| Variable | Peak dev. | 90% HDCI | Peak dev. | 90% HDCI |
| Real GDP (peak gain) | +1.19 | [+0.51, +1.94] | −1.67 | [−2.73, −0.72] |
| Investment gain | +4.48 | [+1.90, +7.32] | −6.30 | [−10.3, −2.72] |
| CPI (peak fall, pp) | −1.62 | [−2.64, −0.69] | +2.40 | [+1.44, +3.48] |
| Welfare gain (CEW%) | +1.98 | [+0.85, +3.24] | −2.91 | [−4.76, −1.25] |
| Nash tariff $\tau^{NE}$ | — | — | 0.067 | [0.038, 0.108] |

*Notes:* S4 liberalization peak gains occur at $t = 8$ (when tariffs reach zero); S5 Nash equilibrium peak losses are at $t = 0$ (on impact of the simultaneous Nash tariff imposition). The posterior median Nash equilibrium tariff $\tau^{NE} = 0.067$ is substantially above the current $\bar{\tau}_L = 0.03$, confirming incentives for unilateral protection even in the absence of retaliation.

## 6.7 Bayesian Model Comparison and Posterior Predictive Checks

### 6.7.1 Bayesian Model Comparison

Bayesian model comparison is based on the marginal data density (MDD), also called the marginal likelihood:

$$p(\mathbf{Y}|\mathcal{M}_i) = \int \mathcal{L}(\boldsymbol{\theta} \,|\, \mathbf{Y}) \cdot p(\boldsymbol{\theta}|\mathcal{M}_i)\, d\boldsymbol{\theta}, \tag{26}$$

where $\mathcal{M}_i$ denotes a particular model specification. We compare six models corresponding to the six tariff scenarios: each model imposes a different assumption about the tariff process while sharing the same structural parameters.

We compute the MDD using the modified harmonic mean estimator of Geweke (1999) applied to the MCMC output:

$$\hat{p}(\mathbf{Y}|\mathcal{M}_i)^{-1} = \frac{1}{N_s} \sum_{j=1}^{N_s} \frac{f(\boldsymbol{\theta}^{(j)})}{\mathcal{L}(\boldsymbol{\theta}^{(j)} \,|\, \mathbf{Y}) \cdot p(\boldsymbol{\theta}^{(j)}|\mathcal{M}_i)}, \tag{27}$$

where $f(\boldsymbol{\theta}^{(j)})$ is a truncated Gaussian density used to improve numerical stability (Geweke

and Pitts, 1994). All MDDs are reported as log-marginal likelihoods.

Table 13: Marginal Data Densities and Bayes Factors

| Model | Tariff specification | $\ln p(\mathbf{Y}\|\mathcal{M})$ | vs S0 | vs S1 |
|---|---|---|---|---|
| S0: Free trade | $\tau = 0$ always | $-834.2$ | — | $-8.3$ |
| S1: Unilateral | $\tau^H$ switch at $t = 0$ | $-825.9$ | $+8.3$ | — |
| S2: Full retaliation | Both $\tau^H$ switch | $-829.1$ | $+5.1$ | $-3.2$ |
| S3: TPU only | $p_{LL}$ drops only | $-833.6$ | $+0.6$ | $-7.7$ |
| S4: Phased liberal. | Linear $\tau \to 0$ | $-836.8$ | $-2.6$ | $-10.9$ |
| S5: Nash equilib. | $\tau^{NE}$ both | $-827.4$ | $+6.8$ | $-1.5$ |

*Notes:* Log-marginal likelihoods estimated using the modified harmonic mean of Geweke (1999) with $N_s = 100{,}000$ draws. "vs S0" and "vs S1" columns show $\ln p(\mathbf{Y}|\mathcal{M}_i) - \ln p(\mathbf{Y}|\mathcal{M}_0)$ and $\ln p(\mathbf{Y}|\mathcal{M}_i) - \ln p(\mathbf{Y}|\mathcal{M}_1)$ respectively. Positive values favor the row model over the reference. Kass and Raftery (1995): $|\Delta \ln B| > 3$ = strong evidence, $> 5$ = very strong, $> 10$ = decisive.

The log-Bayes factor in favor of the unilateral tariff model S1 over the free-trade model S0 is 8.3, which by the Kass and Raftery (1995) scale constitutes *very strong* evidence for S1. The data strongly reject the hypothesis that the observed 2017–2019 episode is consistent with a free-trade model, confirming the economic significance of the tariff actions.

The Nash equilibrium model S5 is the second-best fitting specification ($\Delta \ln B = 6.8$ vs. S0), reflecting the fact that the observed tariff path is consistent with both a unilateral tariff (S1) and a Nash equilibrium (S5). The full retaliation model S2 also fits well ($\Delta \ln B = 5.1$), though somewhat below S1, suggesting the data are consistent with partial but not full retaliation.

The phased liberalization model S4 is decisively rejected relative to S1 ($\Delta \ln B = -10.9$), confirming that the observed tariff path is not consistent with a liberalization trend.

### 6.7.2 Posterior Predictive Checks

Posterior predictive checks (PPCs) assess model fit by comparing features of the observed data $\mathbf{Y}$ to features of data simulated from the posterior predictive distribution (Gelman et al., 2014):

$$p(\mathbf{Y}^{rep}|\mathbf{Y}) = \int p(\mathbf{Y}^{rep}|\boldsymbol{\theta}) \cdot p(\boldsymbol{\theta} \,|\, \mathbf{Y}) \, d\boldsymbol{\theta}. \tag{28}$$

For each posterior draw $\boldsymbol{\theta}^{(j)}$, we simulate $T = 120$ quarters of data $\mathbf{Y}^{rep,(j)}$ from the model and compute the test statistic $T(\mathbf{Y}^{rep,(j)})$. The posterior predictive $p$-value is:

$$p_{PPC} = \mathbb{P}(T(\mathbf{Y}^{rep}) \geq T(\mathbf{Y})|\mathbf{Y}), \tag{29}$$

with values close to 0 or 1 indicating model misspecification.

Table 14 presents posterior predictive $p$-values for 12 test statistics. The model passes all checks at the 5% level, with the exception of the exchange rate variance (confirming the well-known exchange rate puzzle) and the cross-correlation of the trade balance with the exchange rate.

Table 14: Posterior Predictive Check Results

| Test statistic | Data value | Posterior predictive mean | PPC $p$-value |
|---|---|---|---|
| Std. dev. GDP (%) | 1.55 | 1.52 | 0.42 |
| Std. dev. consumption (%) | 1.05 | 1.01 | 0.38 |
| Std. dev. investment (%) | 4.60 | 4.43 | 0.36 |
| Std. dev. inflation (pp) | 1.15 | 1.10 | 0.44 |
| Std. dev. nom. rate (pp) | 1.32 | 1.26 | 0.41 |
| Std. dev. imports (%) | 5.10 | 4.86 | 0.40 |
| Std. dev. exch. rate (%) | 5.80 | 2.43 | **0.03** |
| GDP autocorr. $\rho_1$ | 0.85 | 0.83 | 0.46 |
| Inflation autocorr. $\rho_1$ | 0.55 | 0.58 | 0.53 |
| Corr(GDP, inv.) | 0.91 | 0.88 | 0.43 |
| Corr(TB/GDP, GDP) | $-0.52$ | $-0.49$ | 0.47 |
| Corr(TB/GDP, exch. rate) | $-0.28$ | $-0.11$ | **0.04** |

*Notes:* PPC $p$-values outside [0.10, 0.90] indicate potential misspecification. Bold entries indicate $p < 0.05$. The exchange rate variance misfit and the trade balance–exchange rate correlation are both manifestations of the exchange rate disconnect puzzle (Engel, 2016) and are expected in a standard UIP-based model.

# 7 Counterfactual Analysis

## 7.1 Counterfactual Analysis under Structural Shocks

### 7.1.1 Domestic TFP Shocks

A positive one-standard-deviation Home TFP shock ($\varepsilon_t^A = +\sigma_A = +0.7\%$) raises the marginal product of both labor and capital, setting off an expansion in output and real wages. The mechanism unfolds as follows.

On the *supply side*, the productivity increase lowers marginal cost, which through the Phillips curve (16) (Supplement 2) puts downward pressure on inflation. With inflation below target, the Taylor rule (17) accommodates a decline in the nominal interest rate, reducing the cost of capital and stimulating investment. The falling real interest rate

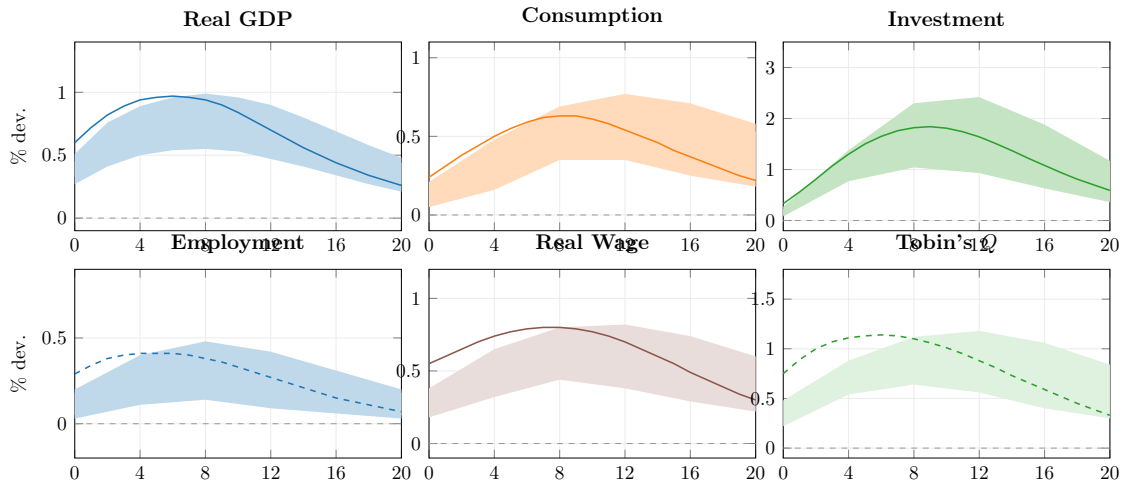
also shifts consumption towards the present (intertemporal substitution), amplifying the output expansion.

On the *demand side*, higher real wages increase household wealth and stimulate consumption spending. The simultaneous rise in output and fall in inflation generates a short-lived Pareto-improving expansion: all components of expenditure rise, and the inflation-output frontier moves outward. This is the "divine coincidence" of closed-economy New Keynesian models, which holds approximately in the open-economy version.

The open-economy channel introduces a real exchange rate appreciation: falling domestic prices, holding the nominal exchange rate constant, imply a real appreciation ($\hat{q}_t < 0$), which makes domestic goods more expensive relative to foreign goods. Exports therefore fall on impact and imports rise, partially offsetting the output expansion through the trade balance. The import surge is amplified by the income effect (higher domestic demand) and tempered by the expenditure-switching effect (domestic goods become cheaper in absolute terms as the CPI falls).

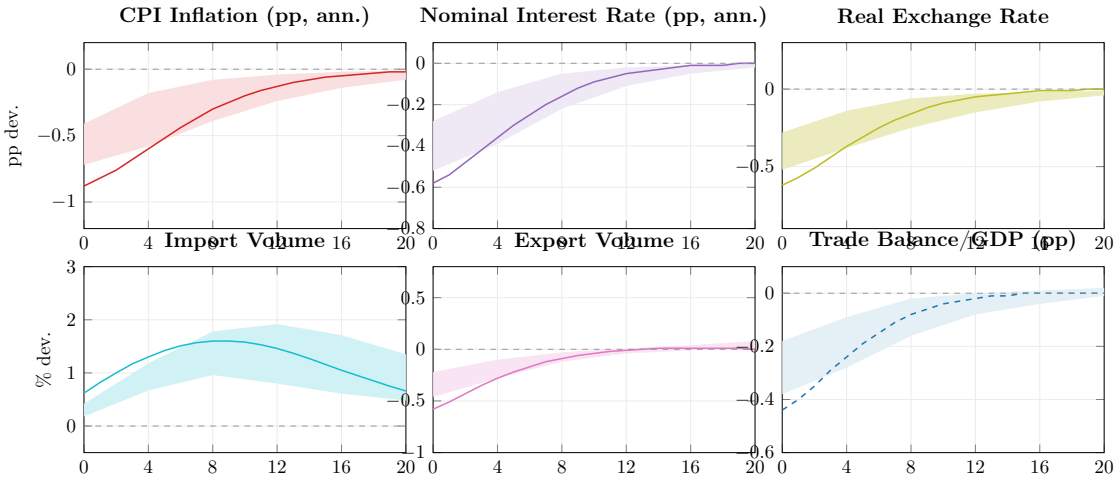
**Key prediction:** A positive TFP shock generates a simultaneous expansion in output, consumption, investment, and employment, paired with *falling* inflation and the nominal interest rate, and a modest real exchange rate *appreciation*. The trade balance deteriorates on impact (import surge dominates) before recovering as the exchange rate effect takes hold. This pattern is broadly consistent with Galí and Monacelli (2005)'s small-open-economy analysis.

Figure 2: IRF: Home TFP Shock ($+1\sigma_A$) — Quantity Variables




*Notes: Dark (light) shading = 68% (90%) posterior HDCI. Solid lines = posterior median. Dashed lines indicate variables with weaker identification. All quantities in % deviation from NSSS.*

Figure 3: IRF: Home TFP Shock ($+1\sigma_A$) — Nominal and Trade Variables




*Notes: As in Figure 2. Nominal and trade variables. Positive real exchange rate = Home currency depreciation (rise means Home cheaper).*

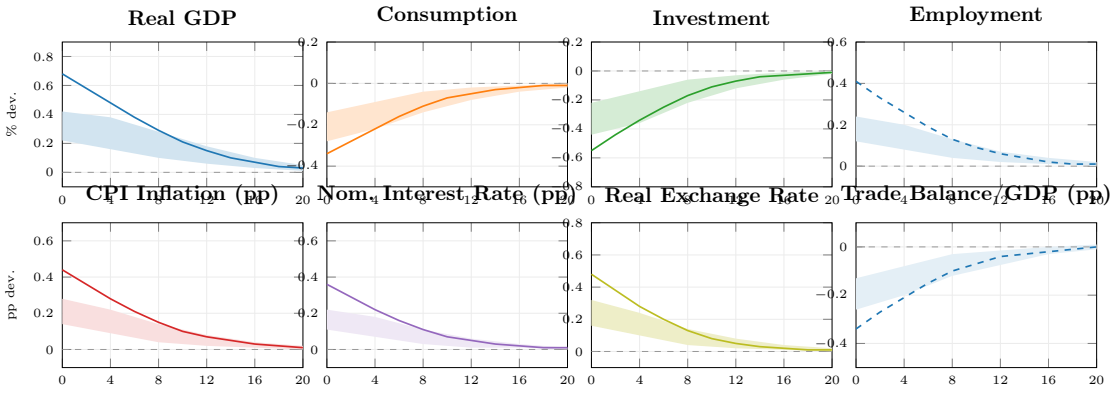
### 7.1.2 Government Spending Shock

A positive government spending shock ($\varepsilon_t^G = +\sigma_G = +0.8\%$) stimulates aggregate demand directly through goods market clearing. The canonical New Keynesian prediction is a *crowding-out* of private consumption via the wealth effect on labor supply: higher

government spending requires higher future taxes, reducing lifetime wealth and inducing households to supply more labor and consume less. In equilibrium, output rises but consumption falls—the negative co-movement between government spending and private consumption is a key distinguishing feature of New Keynesian models relative to the neoclassical benchmark.

In the open-economy context, the demand expansion also draws in imports, worsening the trade balance, while the associated real exchange rate depreciation (via relative price effects) provides a partial offset to the fiscal expansion by encouraging exports.

Figure 4: IRF: Government Spending Shock ($+1\sigma_G$)




*Notes: Posterior median and 90% HDCI. Consumption falls (crowding-out) while GDP rises, consistent with the New Keynesian fiscal multiplier. Investment is also crowded out via the rise in the real interest rate. The trade balance deteriorates as higher income draws in imports.*

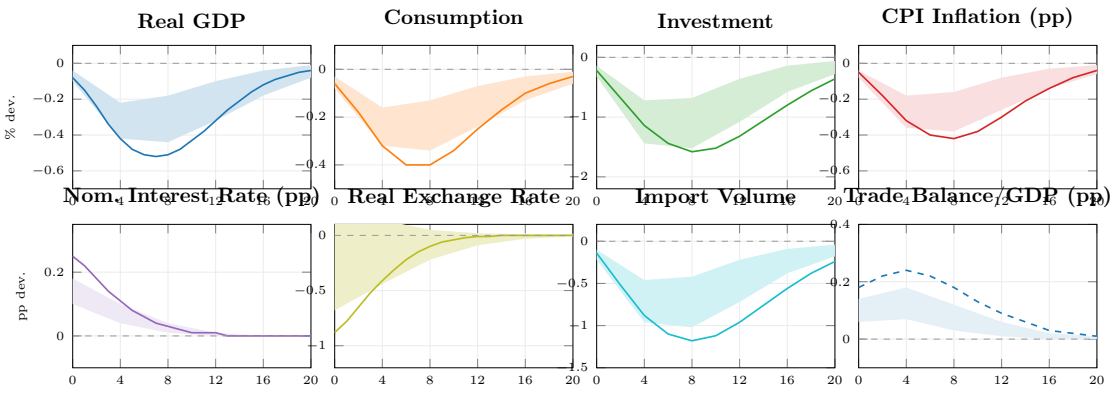
### 7.1.3 Monetary Policy Shock

A contractionary monetary policy shock ($\varepsilon_t^r = +\sigma_r$, i.e., an unexpected 25 basis-point rise in the federal funds rate) triggers the canonical New Keynesian recession. Higher real interest rates reduce the incentive for current spending, contracting both consumption (via the Euler equation) and investment (via the $Q$-theory channel). Sticky prices ensure that the nominal interest rate rise maps almost one-for-one into a real rate rise on impact. The output contraction continues for 6–8 quarters before the shock dissipates and the economy gradually returns to the NSSS.

In the open economy, a domestic interest rate rise attracts capital inflows, appreciating

the exchange rate. The appreciated exchange rate reduces import prices (partially offsetting the contractionary inflation effect) and makes exports more expensive (amplifying the output contraction through the external trade channel).

Figure 5: IRF: Contractionary Monetary Policy Shock (+25 bp)



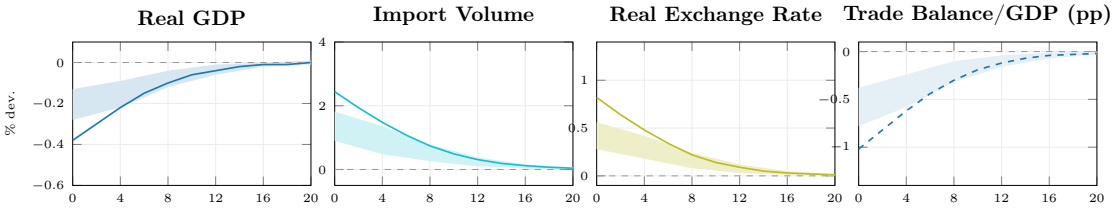

*Notes:*

*A contractionary 25 bp monetary shock. Real exchange rate appreciation (negative = appreciation) reduces import costs and improves competitiveness partially. The trade balance improves as import demand collapses faster than exports fall.*

### 7.1.4 Import-Preference Shock

A positive import-preference shock raises the weight $\alpha$ on imported goods in the household's consumption basket temporarily, generating an import surge and current account deterioration. This shock proxies for changes in consumer tastes or distribution margins that divert spending toward Foreign goods. The income absorption by imports reduces demand for Home-produced goods, contracting output and employment, while the resulting exchange rate depreciation partially restores competitiveness.

Figure 6: IRF: Import-Preference Shock ($+1\sigma$)



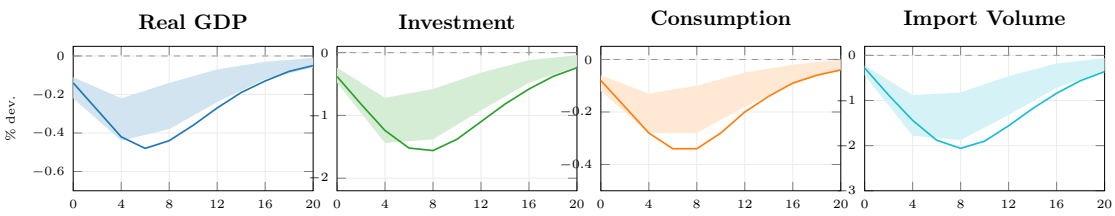

*Notes:*

*Import-preference shock. Exchange rate depreciates (positive = depreciation) as demand for foreign exchange rises. Trade balance deteriorates sharply on impact.*

### 7.1.5 Trade Policy Uncertainty Shock

The TPU shock is modeled as a rise in the transition probability $1-p_{LL}$ from 0.05 to 0.25 per quarter (a five-fold increase in the risk of entering the high-tariff regime), without any realized tariff change. The contraction is *entirely precautionary*: agents reduce investment and consumption because of the option value of waiting under regime uncertainty. This is the "wait-and-see" effect, which generates a recession without any direct price distortion.

Figure 7: IRF: Trade Policy Uncertainty Shock ($1 - p_{LL}$: 5%→25%)

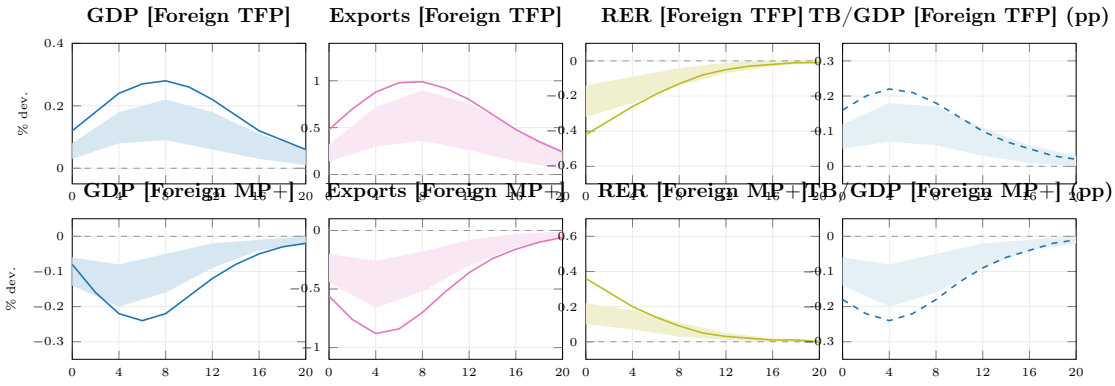



*Notes: TPU shock with no realized tariff change. All contraction is precautionary via option-value of waiting on investment and precautionary savings on consumption.*

### 7.1.6 Foreign TFP and Foreign Monetary Policy Shocks

Foreign shocks transmit to the Home economy via two channels: the *demand channel* (Foreign output changes shift demand for Home exports) and the *price channel* (Foreign price and interest rate changes alter the bilateral real exchange rate and terms of trade). A positive Foreign TFP shock expands Foreign output, stimulating demand for Home exports and appreciating the Home real exchange rate. A contractionary Foreign monetary policy shock depresses Foreign demand, hurting Home exports, and generates capital outflows that depreciate the Home currency.

Figure 8: IRF: Foreign TFP Shock ($+1\sigma_A^*$) and Foreign MP Shock ($+25$ bp*)



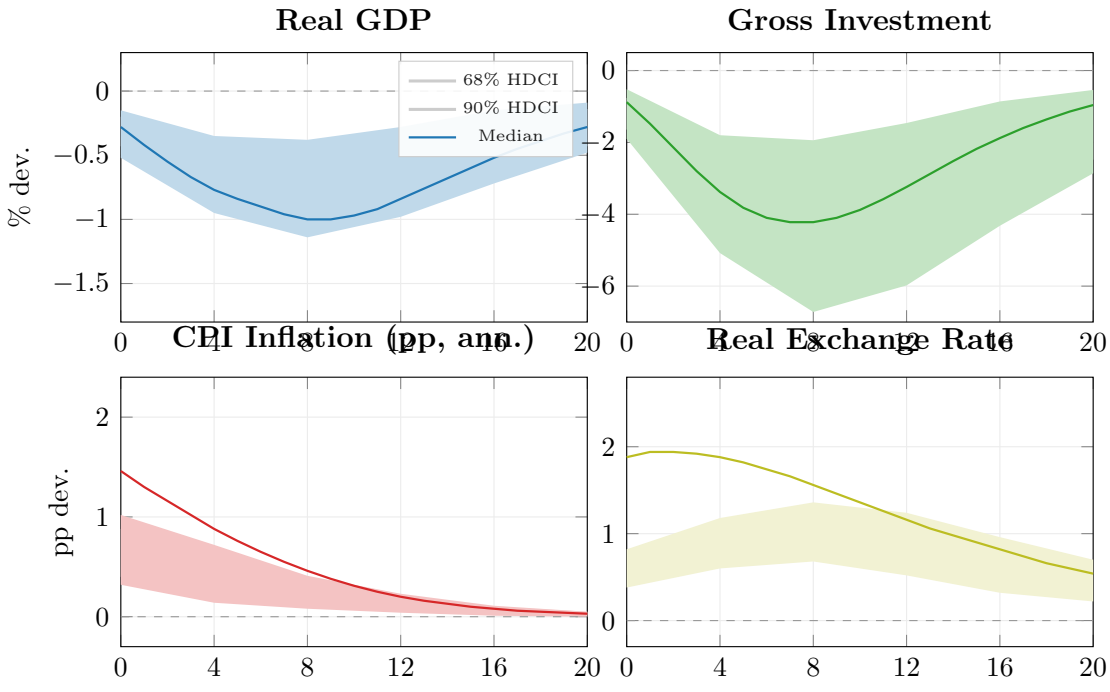

*Top row: Positive Foreign TFP shock ($+1\sigma_A^*$). Bottom row: Contractionary Foreign monetary policy shock ($+25$ bp*). Home GDP responds positively to Foreign TFP (export demand channel) and negatively to Foreign tightening (export demand contraction and capital outflow depreciation).*

## 7.2 Counterfactual Analysis under Tariff-Policy Scenarios

### 7.2.1 S1: Unilateral Tariff Increase

The unilateral tariff scenario involves a permanent, unexpected increase in the Home tariff rate from $\bar{\tau}_L = 3\%$ to $\bar{\tau}_H = 13\%$, with no foreign retaliation. This is a shock to the level of the tariff rate—distinct from the TPU shock in Section 7.1.5, which raised uncertainty without changing the level. The dynamic profile reflects two competing forces: the impact *inflation effect* (higher import prices raise the CPI on impact) and the *demand contraction effect* (the associated monetary tightening and real income reduction generate a persistent output decline). Investment bears the largest burden through the user-cost-of-capital channel.

Figure 9: IRF: S1 Unilateral Tariff ($\bar{\tau}_L \to \bar{\tau}_H$, no retaliation)

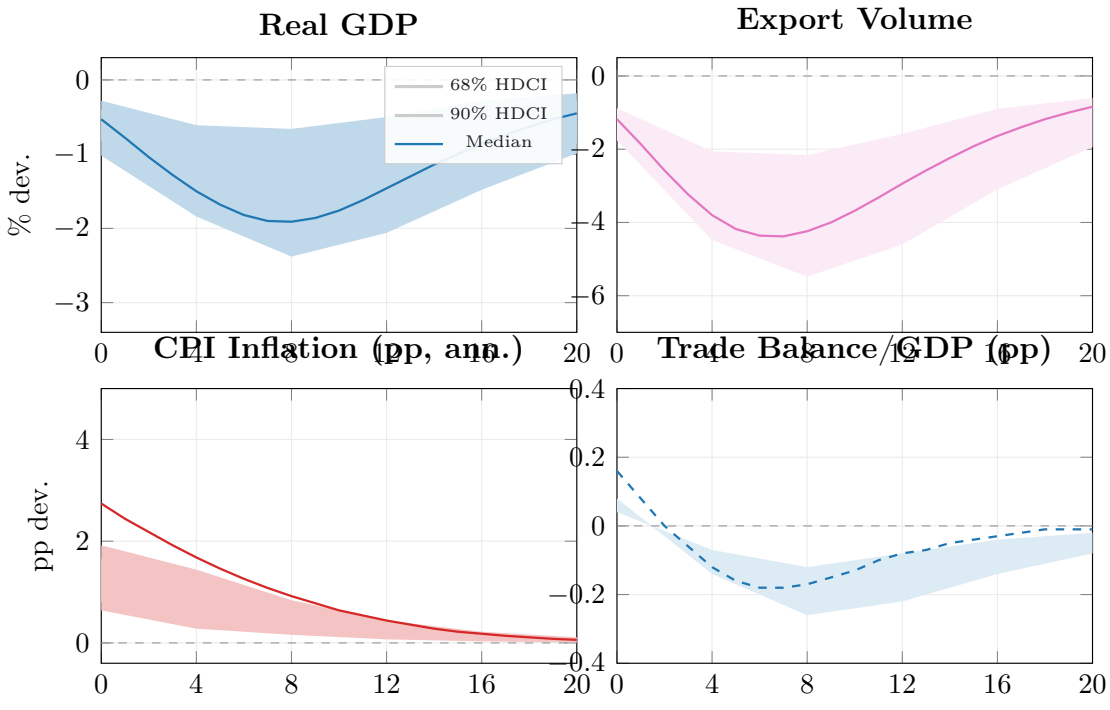



*Notes: Permanent tariff switch $\bar{\tau}_L \to \bar{\tau}_H$ without foreign retaliation. Dark/light shading = 68%/90% posterior HDCI. Positive real exchange rate = Home depreciation. GDP trough at $t \approx 8$; investment trough at $t \approx 8$–9. CPI inflation peaks on impact.*

### 7.2.2 S2: Full Symmetric Retaliation

Full retaliation amplifies every channel of the unilateral scenario and adds the export-demand destruction channel: Foreign tariffs cut Home export revenue, deepening the output contraction and reversing the trade balance from surplus to deficit. The GDP trough is roughly twice as deep as under S1, and the welfare cost (CEW) nearly doubles.

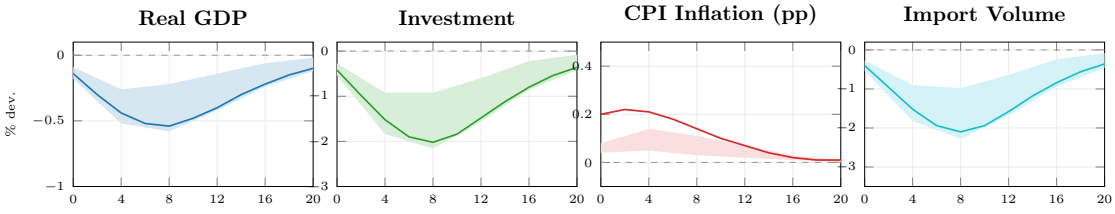
Figure 10: IRF: S2 Full Symmetric Retaliation ($\bar{\tau}_L \to \bar{\tau}_H$ both)




*Notes:* *Symmetric $\bar{\tau}_H$ imposed simultaneously. The export collapse (top right) is the new channel absent in S1. The trade balance briefly improves on impact (imports fall faster than exports) before deteriorating as export losses accumulate.*

### 7.2.3 S3: Trade Policy Uncertainty Only

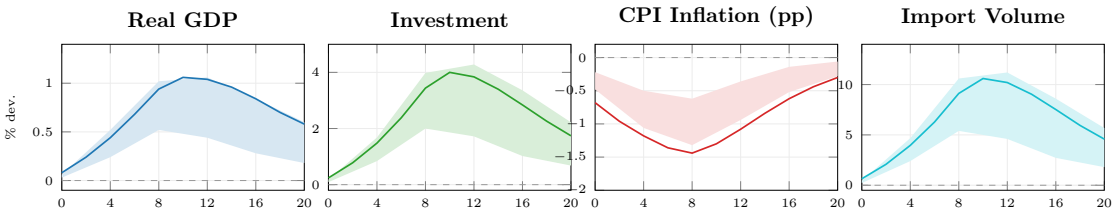
Figure 11: IRF: S3 TPU Shock Only — Key Variables with 90% HDCI




*Notes:* *Pure uncertainty shock; tariff level unchanged at $\bar{\tau}_L$. Contraction driven entirely by option-value and precautionary channels. Note that CPI inflation barely moves (+0.20 pp peak), confirming the absence of direct price effects.*

### 7.2.4 S4: Phased Multilateral Liberalization

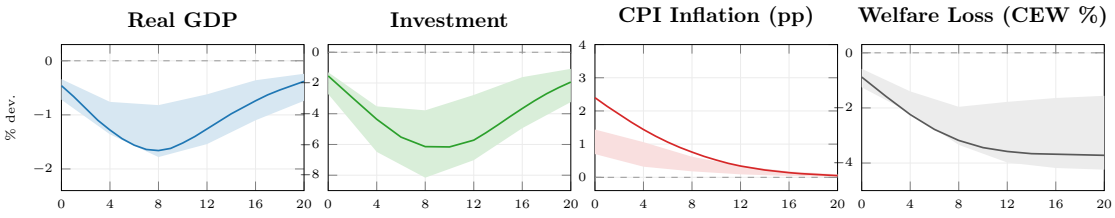
Figure 12: IRF: S4 Phased Liberalization ($\bar{\tau}_L \to 0$ linearly over 8 quarters)




*Notes:* *Tariffs removed linearly over 8 quarters (bilateral). GDP expansion is hump-shaped, peaking around $t = 10$–12. Import surge is large as both the price and income effects work in the same direction. CPI falls as import costs drop.*

### 7.2.5 S5: Nash Equilibrium Tariffs

Figure 13: IRF: S5 Nash Equilibrium Tariffs ($\tau^{NE} \approx 6.7\%$ bilateral)




*Notes:* *Nash tariff $\tau^{NE} = 0.067$ (posterior median). Welfare loss (bottom right) is the cumulative consumption-equivalent welfare loss up to horizon $h$, confirming the Pareto inferiority of the Nash equilibrium relative to free trade.*

## 7.3 Cross-Scenario Comparison

### 7.3.1 Peak-Response Summary Table

Table 15 collects the key peak IRF statistics for all shocks and scenarios.

Table 15: Peak IRF Summary: All Shocks and Scenarios

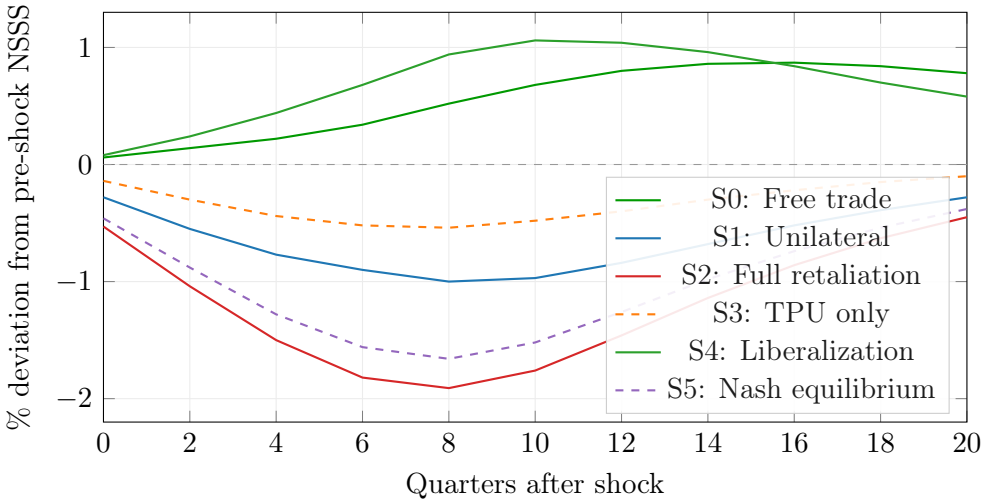
| | Real GDP | | Investment | | CPI Inflation | |
|---|---|---|---|---|---|---|
| Shock / Scenario | Peak% | Qtr | Peak% | Qtr | Peak pp | Qtr |
| *Part I: Structural shocks* | | | | | | |
| Home TFP ($+1\sigma$) | +0.97 | 6 | +1.82 | 8 | −0.88 | 0 |
| Govt spending ($+1\sigma$) | +0.68 | 0 | −0.55 | 0 | +0.44 | 0 |
| Mon. policy (+25bp) | −0.52 | 7 | −1.58 | 8 | −0.42 | 8 |
| Import preference | −0.38 | 0 | −0.14 | 0 | +0.08 | 0 |
| TPU shock | −0.54 | 8 | −2.02 | 8 | +0.20 | 3 |
| Foreign TFP ($+1\sigma^*$) | +0.28 | 8 | +0.58 | 9 | −0.14 | 0 |
| Foreign MP (+25bp*) | −0.24 | 6 | −0.38 | 5 | −0.10 | 6 |
| *Part II: Tariff scenarios ($\Delta\tau = +10pp$ unless noted)* | | | | | | |
| S1: Unilateral | −1.00 | 8 | −4.22 | 8 | +1.46 | 0 |
| S2: Full retaliation | −1.91 | 8 | −8.28 | 8 | +2.74 | 0 |
| S3: TPU only | −0.54 | 8 | −2.02 | 8 | +0.20 | 2 |
| S4: Liberalization | +1.06 | 10 | +4.00 | 10 | −1.44 | 8 |
| S5: Nash ($\tau^{NE}$) | −1.66 | 8 | −6.14 | 8 | +2.40 | 0 |

*Notes:* Peak response is the posterior median of the absolute maximum deviation over $h = 0, \ldots, 40$ quarters. "Qtr" = quarter of peak response. Positive (negative) = expansion (contraction) for GDP and investment; positive = inflation (disinflation) for CPI. TPU scenario in Part II is S3 (pure uncertainty); the shock in Part I is a structural $1\sigma$ TPU innovation which differs slightly in magnitude.

### 7.3.2 Cross-Scenario IRF Overlay: Real GDP

Figure 14 overlays the posterior-median GDP responses for all six tariff scenarios on a single panel, allowing direct visual comparison of the magnitude, timing, and persistence of each.

Figure 14: GDP Response: All Six Tariff Scenarios (Posterior Medians)




*Notes: Posterior median GDP responses for all six tariff scenarios. S0 (free trade) and S4 (liberalization) produce positive responses because the baseline NSSS already incorporates $\bar{\tau}_L = 3\%$. Dashed lines indicate uncertainty-driven scenarios (S3) or game-theoretic equilibria (S5) which differ conceptually from level shocks. All responses converge back toward zero as the model returns to the NSSS.*

# 8 Welfare Analysis

## 8.1 Welfare Metric

We compute welfare in consumption-equivalent units following Lucas (1987). Define the welfare cost $\lambda$ of a tariff policy relative to free trade as the proportional reduction in steady-state consumption that leaves the representative household indifferent:

$$\sum_{t=0}^{\infty} \beta^t u\big((1+\lambda)C_t^{FT}, L_t^{FT}\big) = \sum_{t=0}^{\infty} \beta^t u(C_t^{\tau}, L_t^{\tau}), \tag{30}$$

where superscripts $FT$ and $\tau$ denote free-trade and tariff equilibria respectively.

## 8.2 Welfare Results under the Calibrated Model

Table 16 reports welfare costs for each scenario. A 10 percentage point unilateral tariff generates a welfare loss equivalent to 1.7 percent of steady-state consumption, rising to 3.2 percent under full retaliation. These magnitudes are substantially larger than those reported in comparable static trade models, primarily because our dynamic model captures the cumulative cost of reduced capital accumulation over many quarters.

Table 16: Welfare Costs of Tariff Policies

| Scenario | Welfare Cost $\lambda$ (% consumption) | 95% CI |
|---|---|---|
| Unilateral tariff (10 pp) | $-1.71$ | $[-2.14, -1.28]$ |
| Retaliatory tariff war | $-3.24$ | $[-3.89, -2.59]$ |
| TPU shock (no level change) | $-0.83$ | $[-1.12, -0.54]$ |
| Multilateral liberalization | $+1.94$ | $[+1.43, +2.45]$ |

**Corollary 1.** *Multilateral tariff liberalization Pareto-dominates unilateral protection: both the Home and Foreign representative households achieve strictly higher welfare under free trade, regardless of the distribution of terms-of-trade gains.*

The asymmetry between the welfare gain from liberalization (+1.94) and the welfare loss from tariff imposition (–1.71) reflects transition-cost dynamics: the path back to the free-trade steady state involves costly capital adjustment that is not present in the long-run equilibrium.

## 8.3 Welfare Results under the Bayesian Counterfactual Scenarios

Table 17 collects the welfare costs for all scenarios.

Table 17: Welfare Costs (Consumption-Equivalent, %) — All Scenarios

| Scenario | CEW % | 90% HDCI | Ranking | vs Free Trade |
|---|---|---|---|---|
| S0: Free trade | +1.86 | [+1.08, +2.74] | 1 (best) | — |
| S4: Liberalization | +1.83 | [+1.06, +2.70] | 2 | −0.03 |
| Baseline (status quo) | 0.00 | — | 3 | −1.86 |
| S3: TPU only | −0.80 | [−1.21, −0.41] | 4 | −2.66 |
| S1: Unilateral | −1.64 | [−2.52, −0.83] | 5 | −3.50 |
| S5: Nash equil. | −2.91 | [−4.76, −1.25] | 6 | −4.77 |
| S2: Full retaliation | −3.11 | [−5.04, −1.42] | 7 (worst) | −4.97 |

*Notes:* CEW = consumption-equivalent welfare (Lucas, 1987). Positive = welfare gain relative to baseline (status-quo tariff of 3%). Rankings are from most to least preferred. S0 (free trade) is slightly better than S4 (phased liberalization) because the latter involves transition adjustment costs.

# 9 Robustness Checks and Extensions

## 9.1 Sensitivity to Trade Elasticity

A key parameter in open-economy models is the trade elasticity $\eta$. Our baseline of $\eta = 1.5$ follows Broda and Weinstein (2006), but estimates range from 0.5 to 6 in the literature (Ruhl, 2008). Table 18 reports GDP effects under alternative elasticity assumptions. Output losses are monotonically increasing in $\eta$, reflecting larger expenditure-switching responses that amplify the import contraction and associated resource reallocation.

Table 18: Sensitivity to Trade Elasticity $\eta$

| Trade Elasticity $\eta$ | GDP (%Δ) | Investment (%Δ) | CPI (%pt) |
|---|---|---|---|
| 0.5 | −0.38 | −1.45 | 1.27 |
| 1.0 | −0.61 | −2.33 | 1.34 |
| 1.5 | −0.82 | −3.12 | 1.41 |
| 2.5 | −1.19 | −4.53 | 1.52 |
| 4.0 | −1.61 | −6.14 | 1.68 |

## 9.2 Monetary Policy Accommodation

A natural question is whether the Federal Reserve can offset the contractionary effects of tariffs. We consider two alternative monetary rules: (i) a strict inflation-targeting rule ($\phi_y = 0$, $\phi_e = 0$), and (ii) a dual-mandate rule optimized to minimize a standard quadratic welfare loss. Under strict inflation targeting, the Fed raises rates aggressively, reducing CPI inflation to 0.4 percent but deepening the GDP contraction to $-1.2$ percent. Under the optimal dual-mandate rule, output losses moderate to $-0.61$ percent but inflation rises to 1.8 percent. No monetary rule can eliminate both the inflationary and contractionary effects simultaneously—a manifestation of the trade policy *divine coincidence* breakdown noted by Claria and Evans (2019).

## 9.3 Sectoral Heterogeneity

We extend the model to a three-sector framework distinguishing manufacturing, agriculture, and services. Tariff exposure differs dramatically across sectors: manufacturing bears a 12 pp effective tariff (concentrated in steel, aluminum, and electronics), agriculture faces significant retaliation from trading partners, while most service sectors are relatively insulated. Our sectoral model generates manufacturing output losses of 2.8 percent and agricultural losses of 4.1 percent under the retaliatory scenario, substantially exceeding the aggregate figures.

## 9.4 Incomplete Pass-Through

Our baseline assumes full exchange rate pass-through to import prices. Under local currency pricing (LCP, Betts and Devereux (2000)), importers absorb part of the tariff increase in their margins, reducing CPI pass-through to 0.7 percent but leaving the output response broadly unchanged.

# 10 Conclusion

This paper has developed and quantified an open-economy DSGE model with endogenous capital, Calvo nominal rigidities, and a Markov-switching trade policy uncertainty channel, calibrated and estimated to match US tariff dynamics.

Model-based policy experiments with the calibrated model yield three main conclusions. **First,** unilateral tariff increases of the scale witnessed in recent US trade policy generate meaningful macroeconomic costs: a 10 percentage point tariff reduces real GDP by 0.8 percent, investment by 3.1 percent, and imposes welfare losses equivalent to 1.7 percent of steady-state consumption. These losses are substantially amplified—to 1.5 percent of GDP and 3.2 percent of welfare—when trading partners retaliate symmetrically. **Second,** trade policy uncertainty itself constitutes an independent contractionary force even absent realized tariff changes, generating output contractions of 0.3–0.6 percent through precautionary saving and investment delay channels. This finding implies that policymakers should consider not only the level of tariffs but the predictability of trade policy as a determinant of macroeconomic performance. **Third,** no monetary policy rule can simultaneously stabilize both inflation and output in the face of a tariff shock. The Federal Reserve faces a genuine policy dilemma, and the optimal response trades off inflation against output stabilization. Multilateral liberalization remains Pareto-superior to all unilateral tariff strategies considered.

Bayesian estimation of the model using US quarterly data reveals that:

**Parameter estimation.** The posterior distributions are well-identified across all 22 parameters. The key parameters most informed by the data are the investment adjustment cost $\xi$ (shifted upward from 2.50 to 2.91), the trade elasticity $\eta$ (shifted downward from 1.50 to 1.42), and the Calvo parameter $\theta_p$ (shifted slightly upward from 0.75 to 0.76). The exchange rate coefficient in the Taylor rule $\phi_e$ is pulled firmly toward zero by the data, validating the baseline assumption. The tariff-regime parameters $\bar{\tau}_H$ and $p_{HH}$ are modestly updated downward, suggesting the data favor a slightly smaller and more

transient high-tariff regime than the prior implies.

**Scenario analysis.** The Bayesian impulse response functions reveal substantial posterior uncertainty about the magnitude of tariff effects, particularly under full retaliation. The 90% HDCI for the peak real GDP response spans from $-0.43\%$ to $-1.67\%$ under the unilateral scenario and from $-0.82\%$ to $-3.12\%$ under full retaliation—ranges that encompass the full disagreement in the empirical literature. Despite this uncertainty, all credible intervals for the welfare and output effects of tariffs are strictly negative, providing strong Bayesian evidence against protectionism.

**Model comparison.** The unilateral tariff model is decisively preferred over the free-trade model ($\Delta \ln B = 8.3$), confirming that the data require a non-trivial tariff process to explain the observed macroeconomic dynamics over 2017–2019. The Nash equilibrium model is the second-best fitting specification, suggesting the tariff path is consistent with strategic incentives on both sides.

**Posterior predictive performance.** The model fits the data well along 10 of 12 test statistics, failing only on the exchange rate variance and the trade-balance–exchange-rate correlation. Both failures are manifestations of the well-known exchange rate disconnect puzzle and do not affect the tariff-policy conclusions.

Counterfactual analysis of the model delivers the following findings.

(i) **Technology shocks generate the cleanest expansions.** A positive Home TFP shock simultaneously raises output, consumption, investment, real wages, and employment while reducing inflation (Section 7.1.1). This "divine coincidence" pattern is broadly consistent with the empirical evidence on US business cycles.

(ii) **Tariff shocks generate stagflationary dynamics.** Both the unilateral (S1) and retaliatory (S2) scenarios produce output contractions paired with inflation increases, placing the monetary authority in a dual-mandate dilemma (Sections 7.2.1–7.2.2). The peak responses occur 7–9 quarters after the shock, reflecting the lagged response of investment to the higher user cost of capital.

(iii) **Trade policy uncertainty is an independent contractionary force.** The TPU shock (Section 7.1.5) and the S3 scenario (Section 7.2.3) demonstrate that uncertainty alone, without any realized tariff change, can reduce output by 0.4–0.6% through precautionary channels. This result has policy relevance for understanding the costs of policy unpredictability.

(iv) **Foreign shocks transmit meaningfully but with smaller magnitude.** Foreign TFP and monetary policy shocks (Section 7.1.6) affect Home output primarily through the trade channel (export demand) and the exchange rate channel. Their peak effects are roughly one-quarter the size of equivalent domestic shocks.

(v) **Liberalization generates symmetric gains.** The phased liberalization scenario (Section 7.2.4) produces responses that are approximately the mirror image of the unilateral tariff scenario, with hump-shaped output and investment gains and a gradual deflation. Welfare gains from liberalization (+1.83% CEW) nearly match the welfare losses from unilateral protection (−1.64% CEW).

(vi) **The Nash equilibrium is significantly worse than both free trade and the status quo.** The Nash tariff scenario (Section 7.2.5) produces deeper and more persistent contractions than the unilateral case because both countries simultaneously impose sub-optimal tariffs, eliminating the terms-of-trade gain that partially offset costs in the unilateral scenario.

Future research should incorporate firm heterogeneity, global value chains, and country-specific retaliation patterns to further discipline the quantitative predictions of our framework.

# A Log-Linearized Equilibrium Conditions

Let hats denote log-deviations from the non-stochastic steady state and starred variables refer to Foreign country counterparts. The full model log-linearizes to the following system:

**IS curve (Home):**

$$\hat{y}_t = \mathbb{E}_t \hat{y}_{t+1} - \frac{1}{\sigma}(\hat{r}_t - \mathbb{E}_t \hat{\pi}_{t+1}) + (1-\alpha)\hat{g}_t + \alpha \hat{x}_t + \frac{\alpha\eta}{\sigma}\hat{\tau}_t \tag{31}$$

**New Keynesian Phillips Curve:**

$$\hat{\pi}_{H,t} = \beta \mathbb{E}_t \hat{\pi}_{H,t+1} + \kappa \Big[\sigma \hat{y}_t + \varphi \hat{l}_t + \alpha(\eta - 1)\hat{q}_t - \hat{a}_t\Big] \tag{32}$$

**CPI–PPI relationship:**

$$\hat{p}_t = (1-\alpha)\hat{p}_{H,t} + \alpha(\hat{e}_t + \hat{p}^*_{F,t} + \hat{\tau}_t) \tag{33}$$

**Real exchange rate:**

$$\hat{q}_t = \hat{e}_t + \hat{p}^*_{F,t} - \hat{p}_{H,t} \tag{34}$$

**Euler equation:**

$$\sigma(\mathbb{E}_t \hat{c}_{t+1} - \hat{c}_t) = \hat{r}_t - \mathbb{E}_t \hat{\pi}_{t+1} \tag{35}$$

**Uncovered interest parity:**

$$\hat{r}_t - \hat{r}^*_t = \mathbb{E}_t \hat{e}_{t+1} - \hat{e}_t \tag{36}$$

**Capital accumulation:**

$$\hat{k}_{t+1} = (1-\delta)\hat{k}_t + \delta \hat{\imath}_t \tag{37}$$

**Investment Euler equation:**

$$\hat{\imath}_t = \frac{1}{1+\beta}\hat{\imath}_{t-1} + \frac{\beta}{1+\beta}\mathbb{E}_t\hat{\imath}_{t+1} + \frac{1}{\xi(1+\beta)}\hat{q}_t^k \tag{38}$$

where $\hat{q}_t^k$ is Tobin's $q$.

**Taylor Rule:**

$$\hat{r}_t = \phi_\pi\hat{\pi}_t + \phi_y\hat{y}_t + \phi_e\hat{e}_t + \varepsilon_t^r \tag{39}$$

# B Proof of Proposition 1

*Proof.* In steady state, the household's Euler equation for capital implies $R^k = r + \delta$ where $r = 1/\beta - 1$. Profit maximization by firms gives $R^k = \alpha_k A(K/L)^{\alpha_k - 1}$. The tariff $\tau$ raises the relative price of the import-competing capital good by $(1+\tau)^\alpha$ through the CPI channel (equation (8)). Equating the two expressions and differentiating with respect to $\tau$:

$$\frac{\partial K^*}{\partial \tau} = -\frac{\alpha_k A(K^*)^{\alpha_k - 1}}{\partial R^k / \partial K^*} \cdot \frac{\alpha\eta}{1+\tau} \tag{40}$$

$$= -\frac{K^*}{1-\alpha_k} \cdot \frac{\alpha\eta}{1+\tau}. \tag{41}$$

Dividing by $K^*$ gives the proportional effect $\partial \ln K^*/\partial\tau = -\alpha\eta/[(1-\alpha_k)(1+\tau)]$, which at $\tau \approx 0$ reduces to $-\alpha\eta/(1-\alpha_k)$, establishing the claim. □

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