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By

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YALE UNIVERSITY
Box 208281
New Haven, Connecticut 06520-8281

http://cowles.yale.edu/

Tariffs and Trade Deficits*

Lorenzo Caliendo[†], Samuel Kortum[‡], Fernando Parro[§]

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Abstract

We develop a dynamic multi-country Ricardian trade model with aggregate uncertainty, where trade imbalances emerge as countries exchange goods and assets. We introduce a method for computing counterfactuals in this setting, which doesn't require specifying the stochastic process of shocks or solving for asset prices. Applying the model to tariff shocks, we quantify their effects on prices, income, spending, and trade imbalances. We find that higher U.S. tariffs reduce the U.S. trade deficit through general equilibrium adjustments, but raise domestic prices and lower real consumption. Our findings highlight that movements in trade imbalances are shaped by the structure of global trade and finance, and that attempts to influence external balances through changes in trade barriers carry significant implications for real economic outcomes.

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[†]Yale University - NBER - CESifo

[‡]Yale University

[§]University of Rochester - NBER - CESifo

1 Introduction

Countries are exposed to a myriad of unexpected shocks in their economic environment. As a result, economic agents engage in international asset trade to insure against such risks. This globalization of asset markets has reshaped how consumption aligns with both current and uncertain future income. Taking this force into account is essential for understanding and evaluating recent turmoil in the global economy.

In this study we develop a dynamic multi-country quantitative trade model that jointly determines trade in goods and holdings of state-contingent assets. The model incorporates aggregate uncertainty, with countries facing stochastic shocks to fundamentals such as productivity, trade costs, and, more recently, tariffs. In particular, we model tariff changes as exogenous aggregate shocks and study their effects on equilibrium allocations across alternative scenarios. Unlike most quantitative trade models, trade imbalances emerge endogenously as equilibrium outcomes of optimal intertemporal decisions under uncertainty.

Typically, quantifying the economic implications of shocks to the economic environment is a demanding task. We propose a method that enables us to compare outcomes of a counterfactual state generated by shocks, such as unilateral tariff shocks, to outcomes from the state of the world that generated the data. This parsimonious method is feasible for dynamic stochastic models with an arbitrary number of countries and sectors.

With data for 187 countries we quantify the effects of recent and ongoing uncertain tariff changes, including the *Liberation Day tariff* schedule announced by the United States in April 2025.[1] Our results show that unilateral tariff changes can affect trade imbalances through general equilibrium effects. In particular, we find that an increase in U.S. tariffs—especially those targeted at China—narrows the U.S. trade deficit. This narrowing arises from endogenous adjustments in income, spending, and asset positions across states. Tariff-induced changes in income are partly absorbed in an econ-

[1] See Executive Order (EO) 14257 of April 2, 2025 (Federal Register published document: 2025-06063 (90 FR 15041) (2025)). Trade imbalances figure prominently in EO 14257 to justify increased tariffs: "... U.S. trading partners' economic policies that suppress domestic wages and consumption, as indicated by large and persistent annual U.S. goods trade deficits, constitute an unusual and extraordinary threat to the national security and economy of the United States." The tariff rates proposed in EO 14257 have since been modified many times, most recently in an Executive Order on July 31, 2025.

omy with complete asset markets, as these markets facilitate intertemporal reallocation and allow countries to smooth consumption.

Despite rising U.S. income due to improved terms of trade and tariff revenue, higher domestic prices erode real consumption in United States under a positive tariff shock. In contrast, surplus countries benefit in real terms by smoothing losses in income through increased asset-backed consumption. The gains and losses are unevenly distributed, shaped by each country's initial exposure to trade with the United States, their baseline trade imbalance, and the structure of global trade. We also show that bilateral trade imbalances adjust asymmetrically across partners. U.S. deficits with key trade partners—China, Mexico, Canada, and the European Union—shrink by between one-third and one-half under the positive tariff shock. Thus, our framework highlights that tariffs can induce shifts in the global pattern of imbalances.

We depart from the existing literature on quantitative trade models that assume either balanced trade or exogenous trade imbalances. Instead, we introduce complete asset markets through trade in state-contingent claims, following Arrow (1964) and Debreu (1959). Adding this structure into a general equilibrium trade model endogenizes trade imbalances. Our quantitative trade model builds on Eaton and Kortum (2002) while integrating multiple sectors and tariffs as in Caliendo and Parro (2015).[2]

Our key contribution is to develop a methodology for performing counterfactuals in this multi-country complete-markets setting. By expressing the system of equilibrium conditions in an alternative state of the world relative to data from the actual state, we show how to quantify the effects of aggregate shocks on various outcomes. Importantly, we do not need to infer objects such as state-contingent security prices, the probabilities of different histories, or the Lagrange multipliers associated with each country's budget constraint. Our methodology extends the *exact hat algebra* method (Dekle et al. (2007) and Costinot and Rodríguez-Clare (2014)) to dynamic trade settings under uncertainty.[3]

[2]Our framework with trade in goods and complete markets relates to Fitzgerald (2012), who examines how trade costs influence international risk sharing, finding that trade frictions significantly impede risk sharing across countries even in the absence of asset-market frictions. Similarly Eaton et al. (2016a) find that trade frictions alone are essential in resolving many international macro puzzles.

[3]Our work also relates to dynamic-hat algebra methods in spatial economics, under perfect foresight (Caliendo et al. (2019)) and under uncertainty and evolving beliefs (Fang et al. (2023)).

The framework we propose connects with a growing literature on quantitative trade models featuring endogenous trade imbalances under perfect foresight (e.g., Eaton et al. (2016b) and Reyes-Heroles (2017)), as well as models that incorporate uncertainty regarding trade policies and aggregate shocks (e.g., Alessandria et al. (2024) and Alessandria and Choi (2021)).[4] We build upon this body of work by incorporating complete asset markets under uncertainty. This innovation enables us to analyze how trade imbalances and other outcomes respond to shocks to fundamentals such as productivity, trade costs, and tariffs. Interpreting tariff changes as unanticipated events that occur in a given state of the world, rather than as deliberate government decisions, connects to the public finance literature that studies the economic effects of state-contingent taxes (e.g., Lucas and Stokey (1983) and Stockman (1988)). More related to our paper, Stockman and Dellas (1986) study an environment in which households trade in asset markets and select optimal portfolios of Arrow securities, facing uncertainties about tariffs stemming from random government trade policies. While we can't claim that the complete markets setting perfectly describes reality, we argue that it provides a better benchmark for today's globally integrated world than one in which countries cannot trade securities and must consume their current domestic income.

Finally, our research relates to recent theoretical studies on optimal trade policy and its consequences for trade imbalances, including Itskhoki and Mukhin (2025), Aguiar et al. (2025), Costinot and Werning (2025), and Dávila et al. (2025). We differ from this literature by pursuing a positive analysis and by focussing on the effect of tariff changes on impact rather than across steady states.

Ignatenko et al. (2025) use a static model to quantify the welfare effects of U.S. tariff increases and how these effects are shaped by the retaliation of its trading partners, an issue we don't pursue here.

The rest of the paper is structured as follows. Section 2 lays out the framework

[4]Our work also connects to other models with endogenous trade imbalances and perfect foresight that examine the labor market adjustment to the China shock (Dix-Carneiro et al. (2023)), the impact of trade imbalances on employment in the industrial sector (Kehoe et al. (2018)), and the role of asymmetric trade barriers in shaping bilateral trade imbalances (Cuñat and Zymek (2023)). It also relates to the study of trade policy uncertainty on welfare and trade dynamics (e.g., Handley and Limao (2015), Alessandria et al. (2021), Steinberg (2019)).

with trade in goods, complete markets, and endogenous trade imbalances. Section 3 presents the quantitative analysis, and Section 4 concludes.

2 Model

Consider an economy composed of N countries, indexed by n (typically the importer), i (typically the exporter), and k (as needed). Each country n is endowed with L_n identical infinitely-lived individuals, each supplying a unit of labor inelastically. Time is discrete and indexed by $t = 0, 1, 2, ...$ At each time t the economy faces uncertainty, represented by events in the world $s_t \in S$. We denote a history of such events, or state history, by $s^t = (s_0, s_1, \ldots, s_t) \in S^t$.

Let $\Pi(s^t|s_0)$ denote the probability of observing history $s^t = (s_0, s_1, \ldots, s_t)$ given s_0 (we treat s_0 itself as fixed). This probability measure is non-negative and satisfies:

$$\sum_{s^t \in S^t} \Pi(s^t|s_0) = 1.$$

We can write the conditional probability of any history of the form $s^{t+1} = (s^t, s_{t+1})$, given s^t, as $\Pi(s^{t+1}|s^t) = \Pi(s^{t+1}|s_0)/\Pi(s^t|s_0)$. Note that this expression only applies for histories s^{t+1} that are possible given s^t.

A history s^t specifies, for each country, the fundamentals of the global economy and the resulting economic outcomes as described in Sections 2.1 and 2.2. In particular, the key outcomes include bilateral trade, price levels $p_{n,t}(s^t)$, individual consumption $c_{n,t}(s^t)$, and individual income $y_{n,t}(s^t)$. The underlying stochastic fundamentals include productivity levels $T_i(s^t)$, bilateral iceberg trade costs $d_{ni}(s^t)$, and tariffs $\tau_{ni}(s^t)$ (expressed as one plus the ad-valorem rate that country n applies to imports from country i). This formulation incorporates the possibility of stochastic tariff shocks. While the primary focus of the analysis in this paper is to examine how tariff shocks impact economic outcomes, we also allow for the possibility that economies may experience other events, including fluctuations in productivity and in non-tariff trade costs.

2.1 Asset Markets, the Consumer Problem, and Deficits

We assume asset markets are complete, allowing agents to trade a full set of state-contingent claims at common international prices. Each asset pays one unit of the numéraire conditional on the realization of a specific history and pays nothing otherwise. We denote by $q_t^0(s^t)$ the price at time zero of such an asset, that delivers if and only if state history s^t is realized at date t. International trade in goods takes place after s^t is revealed, with all transactions denominated in terms of the numéraire.[5] Importantly, the initial-period trade in state-contingent assets determines subsequent expenditures available to each country in every potential future state history. Time 0 asset trade in these state-contingent claims is known in the literature as the *Arrow-Debreu* market structure.[6] These forward contracts are the mechanism by which agents transfer resources across countries, across histories, and across time. They enable trade imbalances in the economy.

Consider an individual with intertemporal preferences over consumption paths, discount factor $\beta < 1$, and twice differentiable period utility function $u(c)$ that is strictly increasing and strictly concave. Prior to the realization of uncertainty, the individual chooses a state-contingent consumption plan to maximize expected lifetime utility. Formally, an individual in country n solves:

$$\max_{\{c_{n,t}(s^t)\}} U_n = \sum_{t=1}^{\infty} \sum_{s^t \in S^t} \beta^t \, \Pi(s^t|s_0) \, u\left(c_{n,t}(s^t)\right),$$

subject to the intertemporal budget constraint:

$$\sum_t \sum_{s^t} q_t^0(s^t) \left(p_{n,t}(s^t) \, c_{n,t}(s^t) - y_{n,t}(s^t)\right) = 0.$$

The Lagrangian multiplier on this constraint is λ_n. Recall that $q_t^0(s^t)$ represents the

[5] The ex-ante price at date 0 (in terms of the numéraire) of securing a unit of consumption in history s^t in country n at date t is therefore $q_t^0(s^t)p_{n,t}(s^t)$.

[6] Sargent and Ljungqvist (2012) provide a definitive treatment of equilibrium with complete markets in a closed pure-exchange economy. They show that a market structure in which asset trades occur sequentially delivers the same allocation as one in which all trades occur at date 0, as in the formulation we adopt. We depart from the closed pure-exchange economy by incorporating production of multiple goods, international trade, tariffs, and trade costs.

ex-ante price at time zero of a security delivering one unit of the numéraire at time t if history s^t occurs. Thus, the ex-ante cost of financing consumption spending, given s^t, is $q_t^0(s^t)p_{n,t}(s^t)c_{n,t}(s^t)$. The intertemporal constraint can therefore be interpreted as if the individual sells securities against future income realizations to finance state-contingent consumption plans. The individual's total ex-ante receipts from issuing these state-contingent claims on its income at date t, conditional on s^t, is $q_t^0(s^t)y_{n,t}(s^t)$.

We are interested in this problem because of its implications for how aggregate consumption spending, $X_{n,t}(s^t) = p_{n,t}(s^t)C_{n,t}(s^t) = L_n p_{n,t}(s^t)c_{n,t}(s^t)$, varies separately from aggregate income $Y_{n,t}(s^t) = L_n y_{n,t}(s^t)$, generating *endogenous* trade imbalances. Specifically, at each date t and history s^t, the trade deficit of country n (positive or negative) is:

$$D_{n,t}(s^t) = X_{n,t}(s^t) - Y_{n,t}(s^t).$$

Country n's income comprises labor earnings plus tariff revenue:

$$Y_{n,t}(s^t) = w_{n,t}(s^t)\, L_n + R_{n,t}(s^t), \tag{1}$$

where $w_{n,t}(s^t)$ denotes the wage in country n. Tariff revenue is:

$$R_{n,t}(s^t) = \sum_{i=1}^{N} \big(\tau_{ni,t}(s^t) - 1\big)\, \pi_{ni,t}(s^t)\, \frac{X_{n,t}(s^t)}{\tau_{ni,t}(s^t)},$$

where $\pi_{ni,t}(s^t)$ denotes the fraction of country n's total spending (inclusive of tariffs) that is allocated to goods imported from country i. The determinants of $p_{n,t}(s^t)$, $w_{n,t}(s^t)$, and $\pi_{ni,t}(s^t)$ are described below in Section 2.2.

Trade imbalances reflect intertemporal and state-contingent consumption-smoothing decisions. As we will show, a country's spending in a given history does not depend directly on its current income, but its current income may be directly affected by contemporaneous changes in tariffs. Countries that exhibit relatively low levels of income per worker in a given history s^t due to fundamental shocks will typically run a trade deficit, financed by previously accumulated asset positions; conversely, countries whose income per worker is relatively high in history s^t due to such shocks will typically run a surplus. Importantly, such imbalances arise as an equilibrium outcome of optimal consumption and saving behavior under uncertainty. States of the world characterized by different tariff configurations will induce adjustments in trade imbalances to sustain the optimal consumption allocation despite income changes from adjustments in both the terms of trade and tariff revenue.

Returning to the individual's consumption allocation problem, the first-order condition with respect to $c_{n,t}(s^t)$ is:

$$\beta^t \,\Pi(s^t|s_0) u_c \left(c_{n,t}(s^t)\right) = \lambda_n \, q_t^0(s^t)\, p_{n,t}(s^t), \tag{2}$$

where $u_c(\cdot)$ denotes the marginal utility of consumption. This condition equates discounted expected marginal utility to the cost of the securities needed to provide a unit of consumption in s^t.

We can invert equation (2) to solve for an individual's consumption. Country n's aggregate spending on goods in a given period t and history s^t can then be expressed as:

$$X_{n,t}(s^t) = \frac{p_{n,t}(s^t) L_n \, u_c^{-1}\left(\frac{\lambda_n \, q_t^0(s^t)\, p_{n,t}(s^t)}{\beta^t \,\Pi(s^t|s_0)}\right)}{\sum_k p_{k,t}(s^t) L_k \, u_c^{-1}\left(\frac{\lambda_k \, q_t^0(s^t)\, p_{k,t}(s^t)}{\beta^t \,\Pi(s^t|s_0)}\right)} \, X_t(s^t),$$

where $X_t(s^t) = \sum_i X_{i,t}(s^t)$.

To obtain a sharper characterization of the model, as well as to facilitate empirical implementation, we assume that preferences are of the constant relative risk aversion (CRRA) form:

$$u\left(c\right) \equiv \frac{c^{1-\gamma} - 1}{1-\gamma},$$

where $\gamma > 0$ denotes the coefficient of relative risk aversion and corresponds to the inverse of the elasticity of intertemporal substitution. This specification is widely used in both theoretical and quantitative macroeconomic models, as it allows for tractable solutions while capturing risk-sensitive behavior in intertemporal decision-making.

We can now express country n's aggregate spending in history s^t by substituting in $u_c(c) = c^{-\gamma}$ and hence $u_c^{-1}(x) = x^{-1/\gamma}$:

$$X_{n,t}(s^t) = \frac{L_n \lambda_n^{-1/\gamma} \, p_{n,t}(s^t)^{1-1/\gamma}}{\sum_k L_k \lambda_k^{-1/\gamma} \, p_{k,t}(s^t)^{1-1/\gamma}} \, X_t(s^t). \tag{3}$$

This expression illustrates that spending varies across countries and states as a function of the relative cost of consumption in each country. If the relative risk aversion parameter γ exceeds one, countries facing higher consumption prices in a given history will, all else equal, choose to spend more.

Equation (3) shows that under the CRRA specification any components of the marginal cost of consumption that are common across countries in a given state, $q_t^0(s^t)$, β^t, and $\Pi(s^t|s_0)$, cancel out. As a result, relative spending shares are determined by country-specific terms: the Lagrange multiplier λ_n, the labor supply L_n, and the local price level $p_{n,t}(s^t)$.[7] This equation represents the central departure of our framework from conventional quantitative trade models that assume balanced trade or impose exogenous deficits. In those models, a country's spending is constrained to equal its income, leaving agents fully exposed to country-specific risks, unable to smooth consumption across different economic conditions. Our approach departs from this restrictive benchmark by incorporating state-contingent securities and, as equation (3) demonstrates, each country's spending becomes a share of global spending. In equilibrium that means a country's spending is tied to pooled global income rather than being tied to domestic income alone.

As just noted, global equilibrium requires that global spending equals global income. Thus, in every period and history:

$$\sum_n Y_{n,t}(s^t) = \sum_n X_{n,t}(s^t).$$

[7]Several special cases are worth highlighting. We express them in per-worker terms, letting $x_{n,t}(s^t) = X_{n,t}(s^t)/L_n$: (i) with log utility, as $\gamma \to 1$, spending per worker is constant across states:

$$x_{n,t}(s^t) = \frac{\lambda_n^{-1}}{\sum_i L_i \lambda_i^{-1}};$$

(ii) with perfect risk sharing, as $\gamma \to \infty$, countries choose to equalize consumption per worker:

$$c_{n,t}(s^t) = \frac{x_{n,t}(s^t)}{p_{n,t}(s^t)} = \frac{1}{\sum_i L_i p_{i,t}(s^t)};$$

(iii) with no trade costs, so that price levels are equalized across countries, spending shares become constant across states:

$$x_{n,t}(s^t) = \frac{\lambda_n^{-1/\gamma}}{\sum_i L_i \lambda_i^{-1/\gamma}}.$$

An implication is that the sum of all countries' trade deficits must equal zero:

$$\sum_n D_{n,t}(s^t) = 0.$$

For any given state history, international borrowing by some countries offsets international lending by others.

We choose global spending as the numéraire. Specifically, we normalize global spending in each period and history to unity:

$$X_t(s^t) \equiv \sum_n X_{n,t}(s^t) = 1 \quad \text{for all } t \text{ and } s^t.$$

This normalization is without loss of generality in terms of the model's implications for real outcomes like an individual's consumption $c_{n,t}(s^t)$, the real wage $w_{n,t}(s^t)/p_{n,t}(s^t)$, or real tariff revenue $R_{n,t}(s^t)/p_{n,t}(s^t)$. But it matters for how we interpret the model's implications in data for what would otherwise be nominal variables like spending $X_{n,t}(s^t)$, income $Y_{n,t}(s^t)$, and deficits $D_{n,t}(s^t)$. Each of these variables has a corresponding nominal variable measured in some currency unit, which needs to be normalized by global spending in that same currency unit. In other words, these variables need to be interpreted as shares of global spending.[8]

[8]Having defined the numéraire, and in the special case of log preferences ($\gamma = 1$), we can now solve explicitly for security prices that clear the global market to finance trade imbalance. While not essential for the analysis in the rest of the paper, this derivation provides insight into the complete markets framework. Under log preferences, equation (2) implies:

$$\beta^t \, \Pi(s^t|s_0) = \lambda_n \, q_t^0(s^t) \, p_{n,t}(s^t) c_{n,t}(s^t).$$

Summing across countries and imposing the numéraire, we get:

$$q_t^0(s^t) = \beta^t \, \Pi(s^t|s_0) \sum_n L_n/\lambda_n.$$

With log preferences, security prices reflect discounting, the probability of the state history, and a normalization that depends on the labor supply and Lagrangian multiplier of all countries. Taking the ratio of $q_{t+1}^0(s^{t+1})$ to $q_t^0(s^t)$ we get the price at date t of an asset that pays one unit of the numéraire in s^{t+1}:

$$q_{t+1}^t(s^{t+1}|s_t) = q_{t+1}^0(s^{t+1})/q_t^0(s^t) = \beta \Pi(s^{t+1}|s_t).$$

Summing across all possible states s^{t+1} delivers the global riskless rate in terms of the numéraire, which is simply β. Real returns are nonetheless uncertain due to changes in the spot price of goods, $p_{n,t+1}(s^{t+1})/p_{n,t}(s^t)$, which will typically vary across countries.

2.2 Equilibrium Conditions Given a History

As shown above, the realization of s^t determines the allocation of spending across countries, $X_{n,t}(s^t)$, which is itself a function of relative prices and country-specific characteristics. We now turn to the supply side of the economy to describe the allocation of production and trade conditional on a given history s^t. We adopt the multi-country Ricardian framework of Eaton and Kortum (2002), which features a continuum of tradable goods, $j \in [0, 1]$, with cross-country heterogeneity in production technologies for each good.

Across countries, the efficiency with which goods are produced is drawn independently from a two-parameter Fréchet distribution. Specifically, the probability that a particular good j is produced in country i with labor productivity below z is given by:

$$F_{i,t}(z|s^t) = \exp\left(-T_{i,t}(s^t)z^{-\theta}\right),$$

where $\theta > 1$ governs the dispersion of efficiency draws (i.e., comparative advantage) and $T_{i,t}(s^t) > 0$ is a state-dependent scale parameter that governs country i's absolute advantage.

We assume that labor is the sole factor of production, supplied inelastically in quantity L_i in each country i. Since labor is perfectly mobile within a country, all producers in i can hire workers at wage $w_{i,t}(s^t)$. Producers operate under constant returns to scale. If in country i the productivity of a particular variety is z, then the unit cost of producing that good there is $w_{i,t}(s^t)/z$. Assuming perfect competition, this cost is the price received by a producer of that good in i. Taking account of trade costs and tariffs, this good sells at price $d_{ni,t}(s^t)\tau_{ni,t}(s^t)w_{i,t}(s^t)/z$ in country n.

Consumers in country n will choose to buy from the low-price source for each good. How much they buy is determined by preferences across the unit continuum of goods. We assume CES preferences with elasticity of substitution $\sigma < \theta + 1$, common to all countries. Given the Fréchet-distributed efficiency draws, labor input shares, and cost structures, this setup determines the price distribution, trade shares, and equilibrium wages across countries, all conditional on a given state.

We now present the four equilibrium conditions that characterize the model. The first condition concerns spending. Given price levels, country n's spending is determined by equation (3).

The second condition concerns the price levels themselves. The price index in country n is given by:

$$p_{n,t}(s^t) = \tilde{\Gamma} \left(\sum_i T_{i,t}(s^t) \left(w_{i,t}(s^t)\, d_{ni,t}(s^t)\, \tau_{ni,t}(s^t) \right)^{-\theta} \right)^{-1/\theta}, \tag{4}$$

where $\tilde{\Gamma}$ stands for $\Gamma(1 - (\sigma - 1)/\theta)^{1/(1-\sigma)}$ and $\Gamma(a) = \int_0^\infty x^{a-1} e^{-x} dx$ is the gamma function.

The third condition concerns bilateral trade shares. Applying the properties of the Fréchet distribution, we obtain the probability that a consumer in n will find a producer in i to be the low-price source of a given good. This probability becomes the share of country n's spending allocated to goods produced in country i:

$$\pi_{ni,t}(s^t) = T_{i,t}(s^t) \left(\frac{w_{i,t}(s^t)\, d_{ni,t}(s^t)\, \tau_{ni,t}(s^t)}{p_{n,t}(s^t)/\tilde{\Gamma}} \right)^{-\theta}. \tag{5}$$

The last condition concerns labor-market clearing. The total income earned by labor in country i equals the total revenue it receives from producing goods sold to all destinations:

$$w_{i,t}(s^t)\, L_i = \sum_n \pi_{ni,t}(s^t)\, \frac{X_{n,t}(s^t)}{\tau_{ni,t}(s^t)}. \tag{6}$$

On the right-hand side of the equation, $\pi_{ni,t}(s^t)\, X_{n,t}(s^t)/\tau_{ni,t}(s^t)$ represents the value of country n's effective (net-of-tariff) demand for goods from country i. Summing over all n yields the income flowing to i from goods sold globally, including goods sold in country i itself. This value must equal the total payments to labor in country i so that the labor market clears at wage $w_{i,t}(s^t)$.

With values for all of the parameters and Lagrangian multipliers, in principle we could solve this system of equations, (3)-(6), for country-level spending, wages, prices, and bilateral trade flows. In general there is not a closed-form solution.[9]

[9]The case of autarky, with infinite iceberg costs or tariffs ($d_{ni,t}(s^t) \to \infty$ or $\tau_{ni,t}(s^t) \to \infty$), is an exception. In that case equation (4) collapses to $p_{n,t}(s^t) = \tilde{\Gamma}\, T_{n,t}(s^t)^{-1/\theta} w_{n,t}(s^t)$, equation (3) becomes $X_{n,t}(s^t) = w_{n,t}(s^t) L_n$, and individual consumption is $c_{n,t}(s^t) = \tilde{\Gamma}^{-1}\, T_{n,t}(s^t)^{1/\theta}$. Substituting these

Before proceeding we take stock by noting that the system of equations described above corresponds to the standard one-sector Eaton and Kortum (2002) framework, with a key departure: we do not impose trade balance at the country level. Specifically, we *do not* require that spending equals income (both net of tariffs) for each country i and state s^t. Instead, our formulation in terms of Arrow securities relaxes this condition.

Moreover, in contrast to Dekle et al. (2007), who do allow for trade imbalances, we do not treat them as fixed or subject to exogenous manipulation in a counterfactual. Instead, trade imbalances in our model emerge endogenously as equilibrium outcomes, reflecting optimal intertemporal and state-contingent consumption and saving decisions. In particular, the deficit emerges from the solution to our four equilibrium conditions as the difference between spending (3) and income (1).

In practice, we will solve this system without knowing the Lagrangian multipliers, or many of the underlying parameters, by computing changes relative to baseline values, as described next.

2.3 Counterfactuals

This framework offers a precise interpretation of a counterfactual analysis under uncertainty. Consider a particular state history $s^t = (s_0, s_1, \ldots, s_t)$ that has been realized, where s_t denotes the most recent event, at time t. This history determines the equilibrium allocations at time t, and hence the data we observe.

results into equation (2), together with CRRA preferences, implies:

$$\beta^t \Pi(s^t|s_0)\tilde{\Gamma}^{\gamma} T_{n,t}(s^t)^{-\gamma/\theta} = \lambda_n q_t^0(s^t)\tilde{\Gamma}\, T_{n,t}(s^t)^{-1/\theta} w_{n,t}(s^t).$$

Imposing the numéraire, $\sum_i w_{i,t}(s^t)L_i = 1$, gives us the price of an Arrow security in autarky:

$$q_t^0(s^t) = \beta^t \Pi(s^t|s_0)\tilde{\Gamma}^{\gamma-1} \sum_{i=1}^{N} (L_i/\lambda_i) T_{i,t}(s^t)^{(1-\gamma)/\theta}.$$

The presence of complete asset markets, even with no net trade across countries, gives meaning to relative wages and relative price levels across countries in autarky:

$$\frac{w_{n,t}(s^t)}{w_{k,t}(s^t)} = \left(\frac{T_{n,t}(s^t)}{T_{k,t}(s^t)}\right)^{(1-\gamma)/\theta} \frac{\lambda_k}{\lambda_n} \qquad\qquad \frac{p_{n,t}(s^t)}{p_{k,t}(s^t)} = \left(\frac{T_{n,t}(s^t)}{T_{k,t}(s^t)}\right)^{-\gamma/\theta} \frac{\lambda_k}{\lambda_n}.$$

A natural counterfactual question then arises: how would the equilibrium allocations at time t differ if, instead of the event s_t, a different event $\tilde{s}_t$ had occurred? In this thought experiment, the two histories up to time $t-1$ are identical in both scenarios—i.e., $s^{t-1} = (s_0, s_1, \ldots, s_{t-1})$—but diverge in the last period. That is, we compare the history $s^t = (s^{t-1}, s_t)$, for which we observe the outcome in the data, with a counterfactual history $\tilde{s}^t = (s^{t-1}, \tilde{s}_t)$, that deviates only due to the event at date t.[10]

To implement such a counterfactual, we consider potential changes in fundamentals across the two histories, $s^t = (s^{t-1}, s_t)$ and $\tilde{s}^t = (s^{t-1}, \tilde{s}_t)$. We use hat notation to capture the *proportional change* in any variable x in the counterfactual state history $x(\tilde{s}^t)$ relative to it's value in the realized state $x(s^t)$. Hence, for any exogenous fundamental or any endogenous outcome of the model, we define $\hat{x} = x(\tilde{s}^t)/x(s^t)$, which we will simply call the counterfactual *change* in x. In particular, to capture how the exogenous variables in the model are shocked due to a counterfactual event at date t, we define the following changes in fundamentals: $\hat{T}_{n,t} = T_{n,t}(\tilde{s}^t)/T_{n,t}(s^t)$ (productivity shocks), $\hat{d}_{ni,t} = d_{ni,t}(\tilde{s}^t)/d_{ni,t}(s^t)$ (trade costs shocks), and $\hat{\tau}_{ni,t} = \tau_{ni,t}(\tilde{s}^t)/\tau_{ni,t}(s^t)$ (tariff shocks).

The relevant data observed under the realized state s^t are:

$$\left\{ w_{i,t}(s^t)L_i, X_{n,t}(s^t), \pi_{ni,t}(s^t), \tau_{ni,t}(s^t) \right\}_{i,n=1}^{N}.$$

Given these observations, our goal is to solve for changes in equilibrium outcomes under the counterfactual state $\tilde{s}^t$. The outcomes, expressed as counterfactual changes, are: $\hat{X}_{n,t} = X_{n,t}(\tilde{s}^t)/X_{n,t}(s^t)$, $\hat{p}_{n,t} = p_{n,t}(\tilde{s}^t)/p_{n,t}(s^t)$, $\hat{\pi}_{ni,t} = \pi_{ni,t}(\tilde{s}^t)/\pi_{ni,t}(s^t)$, and $\hat{w}_{i,t} = w_{i,t}(\tilde{s}^t)/w_{i,t}(s^t)$. We solve for $\{\hat{X}_{n,t}, \hat{p}_{n,t}, \hat{\pi}_{ni,t}, \hat{w}_{i,t}\}$ that satisfy the following system of equations for changes in spending, price levels, bilateral trade shares, and labor incomes:

$$\hat{X}_{n,t} = \frac{\hat{p}_{n,t}^{1-1/\gamma}}{\sum_k X_{k,t}(s^t)\hat{p}_{k,t}^{1-1/\gamma}}, \tag{7}$$

[10]In our setup, with complete markets and uncertain states, counterfactuals can be thought of as *stochastic comparative statics*. The distinction from *deterministic comparative statics*, as in a perfect foresight dynamic environment, is that agents in the model have anticipated the possibility of the counterfactual event under consideration. Patrick Kehoe's discussion of Stockman (1988) articulates the conceptual advantage of stochastic comparative statics over deterministic comparative statics.

$$\hat{p}_{n,t} = \left(\sum_i \pi_{ni,t}(s^t) \hat{T}_{i,t} \left(\hat{w}_{i,t} \hat{d}_{ni,t} \hat{\tau}_{ni,t} \right)^{-\theta} \right)^{-1/\theta}, \tag{8}$$

$$\hat{\pi}_{ni,t} = \hat{T}_{i,t} \left(\frac{\hat{w}_{i,t} \hat{d}_{ni,t} \hat{\tau}_{ni,t}}{\hat{p}_{n,t}} \right)^{-\theta}, \tag{9}$$

$$w_{i,t}(s^t) L_i \hat{w}_{i,t} = \sum_n \pi_{ni,t}(s^t) \frac{X_{n,t}(s^t)}{\tau_{ni,t}(s^t)} \hat{\pi}_{ni,t} \frac{\hat{X}_{n,t}}{\hat{\tau}_{ni,t}}. \tag{10}$$

The solution yields the full set of counterfactual general equilibrium outcomes corresponding to the alternative event $\tilde{s}_t$.

The method described above is in the spirit of the exact-hat-algebra approach commonly used in quantitative trade models, extended here to accommodate economies with uncertainty. The key advantage of this methodology lies in its ability to conduct rich counterfactual analyses without requiring full identification or estimation of all structural parameters of the model.

In particular, note that the counterfactual system in hat variables does not require us to compute the Lagrange multipliers λ_n that represent the shadow value of wealth. While fundamental in determining the equilibrium in levels, see equation (3), the multipliers drop out in changes as in equation (7). The multipliers are embedded in the observed data on spending levels, $X_{n,t}(s^t)$, that form the baseline of the counterfactual.

Having solved for $\{\hat{X}_{n,t}, \hat{p}_{n,t}, \hat{\pi}_{ni,t}, \hat{w}_{i,t}\}$, we can compute changes in other outcomes. Examples are the ratio of individual consumption in the counterfactual relative to its value in the realized state s^t, given by $\hat{c}_{n,t} = \hat{X}_{n,t}/\hat{p}_{n,t}$, and the corresponding change in the real wage, $\hat{w}_{n,t}/\hat{p}_{n,t}$. Our choice of numéraire means $\hat{X}_{n,t}$ is the change in the share of global spending taking place in country n. The expression for the change in consumption means that the change in prices in any country n is measured relative to the change in global spending. The expression for the change in the real wage implies that changes in wages are also measured relative to the change in global spending.

Together with the data observed in state s^t, we can compute additional counterfactual outcomes in levels as well. Counterfactual spending in country n is $X_{n,t}(\tilde{s}^t) = X_{n,t}(s^t)\hat{X}_{n,t}$, counterfactual bilateral trade shares are $\pi_{ni,t}(\tilde{s}^t) = \pi_{ni,t}(s^t)\hat{\pi}_{ni,t}$, and counterfactual tariff revenue is:

$$R_{n,t}(\tilde{s}^t) = \sum_i \big(\tau_{ni,t}(\tilde{s}^t) - 1\big)\, \pi_{ni,t}(\tilde{s}^t) \frac{X_{n,t}(\tilde{s}^t)}{\tau_{ni,t}(\tilde{s}^t)}.$$

The numeraire also must apply to the counterfactual level of spending, as can be confirmed from equation (7):

$$\sum_n X_{n,t}(\tilde{s}^t) = \sum_n X_{n,t}(s^t)\hat{X}_{n,t} = \sum_n X_{n,t}(s^t) \frac{\hat{p}_{n,t}^{1-1/\gamma}}{\sum_k X_{k,t}(s^t)\hat{p}_{k,t}^{1-1/\gamma}} = 1.$$

For our analysis here, a key counterfactual outcome is each country's trade imbalance. In state $\tilde{s}^t$, country n's counterfactual deficit is:

$$\begin{aligned} D_{n,t}(\tilde{s}^t) &= X_{n,t}(\tilde{s}^t) - Y_{n,t}(\tilde{s}^t), \\ &= X_{n,t}(\tilde{s}^t) - \big(w_{n,t}(\tilde{s}^t)L_n + R_{n,t}(\tilde{s}^t)\big) \\ &= \sum_{i \neq n} \pi_{ni,t}(\tilde{s}^t) \frac{X_{n,t}(\tilde{s}^t)}{\tau_{ni,t}(\tilde{s}^t)} - \sum_{i \neq n} \pi_{in,t}(\tilde{s}^t) \frac{X_{i,t}(\tilde{s}^t)}{\tau_{in,t}(\tilde{s}^t)}. \end{aligned}$$

The last line reflects that it is the difference between the value of a country's exports and the value of its imports (both net of tariffs). We can thus examine how trade imbalances evolve, given baseline quantities under s^t, in response to changes in productivity, tariffs, or trade costs.

We can also compute *bilateral* trade imbalances. Let $D_{ni,t}(\tilde{s}^t)$ denote the bilateral deficit of country n with country i under the counterfactual state $\tilde{s}^t$. It is simply the difference between imports by n from i and exports to i from n (again, net of tariffs):

$$D_{ni,t}(\tilde{s}^t) = \pi_{ni,t}(\tilde{s}^t) \frac{X_{n,t}(\tilde{s}^t)}{\tau_{ni,t}(\tilde{s}^t)} - \pi_{in,t}(\tilde{s}^t) \frac{X_{i,t}(\tilde{s}^t)}{\tau_{in,t}(\tilde{s}^t)}.$$

The counterfactual bilateral deficit is simply the i'th term from the expression for the overall deficit, so that:

$$\sum_i D_{ni,t}(\tilde{s}^t) = D_{n,t}(\tilde{s}^t).$$

The framework can therefore be used to evaluate the effects of uncertain changes to trade policies—such as country-pair-specific tariffs—on the geography of trade surpluses and deficits, one goal of the quantitative section that follows.

Among the various counterfactual scenarios we could consider the most extreme is autarky, an economy with no goods trade and hence no trade imbalance. This counterfactual delivers a clean expression for the change in real consumption, including the ex-post current value of intertemporal trade.[11] Formally, the autarky counterfactual considers a state history $\tilde{s}^t$ in which bilateral trade is shut down, either because iceberg trade costs or tariffs approach infinity ($d_{ni,t}(\tilde{s}^t) \to \infty$ or $\tau_{ni,t}(\tilde{s}^t) \to \infty$ for all $i \neq n$). In such a scenario, each country consumes only domestically produced goods.

Let $\hat{X}_{n,t}$ denote the change in country n's total spending in autarky relative to the observed state, and let $\hat{p}_{n,t}$ denote the corresponding change in its consumption price index. Then the change in real consumption in autarky relative to the current state is given by:

$$\frac{\hat{X}_{n,t}}{\hat{p}_{n,t}} = \pi_{nn,t}(s^t)^{1/\theta} \left(\frac{w_{n,t}(s^t) L_n}{X_{n,t}(s^t)} \right), \tag{11}$$

where $\pi_{nn,t}(s^t)$ is the share of country n's spending on domestically produced goods, $w_{n,t}(s^t) L_n$ is labor income, $X_{n,t}(s^t)$ is total spending, all as observed in the current state.[12] This expression reflects two distinct components. The term $\pi_{nn,t}(s^t)^{1/\theta}$ captures the static losses from moving to autarky, reflecting lost access to lower-cost imported goods (the inverse of the standard gains from trade). When a country is open to trade, its domestic spending share is less than one, which captures the loss of intratemporal gains from trade in a shift to autarky. The term $w_{n,t}(s^t) L_n / X_{n,t}(s^t)$ captures the ex-post current gains or losses from losing intertemporal trade, that had been facilitated by complete financial markets. These two components capture the effects of a move to autarky. The formula is intuitive and is readily computable from data and a single parameter.

[11]Our measure, however, does not capture the ex-ante value of intertemporal trade, since it conditions on both the initial and counterfactual state history. See Fitzgerald (2024) for a quantification of this ex-ante value.

[12]To derive this result we invert equation (16), setting $i = n$, $\hat{T}_{n,t} = 1$, and $\hat{\pi}_{nn,t} = 1/\pi_{nn,t}(s^t)$ since $\pi_{nn,t}(\tilde{s}^t) = 1$ in a state of autarky. This inversion yields $\hat{w}_{n,t}/\hat{p}_{n,t} = \pi_{nn,t}(s^t)^{1/\theta}$. The result then follows by noting that $\hat{X}_{n,t} = \hat{w}_{n,t}(w_{n,t}(s^t)L_n)/X_{n,t}(s^t)$ since $X_{n,t}(\tilde{s}^t) = w_{n,t}(\tilde{s}^t)L_n$ in a state of autarky.

3 Quantitative Analysis

In this section, we quantify the role of tariffs in shaping trade imbalances and other outcomes through the lens of our framework with trade in goods and assets. In Section 3.1, we extend the framework to incorporate a non-tradable sector and intermediate goods. Section 3.2 describes the main data sources used to recover the observed allocations necessary to take the model to the data. In Sections 3.3 and 3.4, we present the quantitative analysis and discuss our main findings.

3.1 Adding Sectors and Intermediate Goods

To help the model fit the data, we incorporate a non-tradable sector alongside the tradable sector, allowing for both final consumption and intermediate input linkages. This extension preserves the structure of the basic model for tradable goods, but introduces sectoral asymmetries in production and input use.

We assume that aggregate consumption in country n at time t, given history s^t, is a Cobb–Douglas function combining consumption of tradable goods and non-tradable goods:

$$C_{n,t}(s^t) = \left(C_{n,t}^T(s^t)/\alpha\right)^{\alpha} \left(C_{n,t}^{NT}(s^t)/(1-\alpha)\right)^{1-\alpha}.$$

Collectively, individuals allocate a share $\alpha \in (0,1]$ of aggregate final spending $X_{n,t}(s^t)$ to tradables and $1-\alpha$ to non-tradables in order to maximize this Cobb-Douglas consumption aggregator. The corresponding price index for aggregate consumption is:

$$p_{n,t}(s^t) = p_{n,t}^T(s^t)^{\alpha} p_{n,t}^{NT}(s^t)^{1-\alpha}.$$

Let $Y_{i,t}^T(s^t)$ and $Y_{i,t}^{NT}(s^t)$ denote gross output of the tradable and non-tradable sectors. We assume a simple round-about production structure where tradables require tradable intermediate goods, and non-tradables require non-tradable intermediates. Let β^T and β^{NT} denote the value added shares of gross output in the tradable and non-tradable sectors, so that $1-\beta^T$ and $1-\beta^{NT}$ are the intermediate shares. Sectoral spending consists of spending on consumption and on intermediates. It follows that total spending on tradables is:

$$X_{i,t}^{T}(s^t) = \alpha X_{i,t}(s^t) + (1-\beta^T) Y_{i,t}^{T}(s^t),$$

and on non-tradables is:

$$X_{i,t}^{NT}(s^t) = (1-\alpha) X_{i,t}(s^t) + (1-\beta^{NT}) Y_{i,t}^{NT}(s^t).$$

Since a country's total spending on non-tradables equals its gross output in the non-tradables sector, we get:

$$X_{i,t}^{NT}(s^t) = Y_{i,t}^{NT}(s^t) = \frac{1-\alpha}{\beta^{NT}} X_{i,t}(s^t). \tag{12}$$

Spending on tradables, partly driven by demand for intermediates in country i to produce for the global market, is:

$$X_{i,t}^{T}(s^t) = \alpha X_{i,t}(s^t) + (1-\beta^T) \sum_{n=1}^{N} \pi_{ni,t}(s^t) \frac{X_{n,t}^{T}(s^t)}{\tau_{ni,t}(s^t)}.$$

Labor is perfectly mobile across sectors within each country. Spending on labor in the non-tradable sector is $\beta^{NT} Y_{i,t}^{NT}(s^t)$ and in the tradable sector is $\beta^T Y_{i,t}^{T}(s^t)$. Total spending on labor is thus:

$$w_{i,t}(s^t) L_i = (1-\alpha) X_{i,t}(s^t) + \frac{\beta^T}{1-\beta^T} \left(X_{i,t}^{T}(s^t) - \alpha X_{i,t}(s^t) \right).$$

We denote productivity in non-tradables by $A_{n,t}(s^t)$. Hence the price of nontradables in country n is:

$$p_{n,t}^{NT}(s^t) = \frac{1}{A_{n,t}(s^t)} w_{n,t}(s^t)^{\beta^{NT}} p_{n,t}^{NT}(s^t)^{1-\beta^{NT}} = A_{n,t}(s^t)^{-1/\beta^{NT}} w_{n,t}(s^t).$$

Productivity in the tradables sector is determined by the scale parameter of the Frechet distribution, $T_{n,t}(s^t)$, as in the basic model. Taking into account the option to import, the price of tradables in country n is:

$$p_{n,t}^T(s^t) = \tilde{\Gamma} \left(\sum_{i=1}^N T_{i,t}(s^t) \left(w_{i,t}(s^t)^{\beta^T} p_{i,t}^T(s^t)^{1-\beta^T} d_{ni,t}(s^t) \tau_{ni,t}(s^t) \right)^{-\theta} \right)^{-1/\theta}.$$

Finally, following the logic of the basic model, the bilateral trade equation is:

$$\pi_{ni,t}(s^t) = T_{i,t}(s^t) \left(\frac{w_{i,t}(s^t)^{\beta^T} p_{i,t}^T(s^t)^{1-\beta^T} d_{ni,t}(s^t) \tau_{ni,t}(s^t)}{p_{n,t}^T(s^t)/\tilde{\Gamma}} \right)^{-\theta}.$$

Given a history s^t, an equilibrium consists of spending $\{X_{i,t}(s^t), X_{i,t}^T(s^t), X_{i,t}^{NT}(s^t)\}$, prices $\{p_{i,t}(s^t), p_{i,t}^T(s^t), p_{i,t}^{NT}(s^t)\}$, wages $\{w_{i,t}(s^t)\}$, and trade shares $\{\pi_{ni,t}(s^t)\}$ that jointly satisfy the equations above, together with equation (3). This system, including the lagrange multipliers $\{\lambda_n\}$, characterizes the equilibrium of an economy with final consumption and intermediate linkages across tradable and non-tradable sectors.

We follow the exact-hat methodology described in Section 2.3 to express the system of equilibrium conditions for counterfactual changes in spending $\{\hat{X}_{n,t}, \hat{X}_{n,t}^T\}$, prices $\{\hat{p}_{n,t}, \hat{p}_{n,t}^T\}$, bilateral trade shares $\{\hat{\pi}_{ni,t}\}$, and wages $\{\hat{w}_{i,t}\}$:

$$\hat{X}_{n,t} = \frac{\hat{p}_{n,t}^{1-1/\gamma}}{\sum_k X_{k,t}(s^t) \hat{p}_{k,t}^{1-1/\gamma}}, \tag{13}$$

$$\hat{p}_{n,t}^T = \left(\sum_i \pi_{ni,t}(s^t) \hat{T}_{i,t} \left(\left(\hat{w}_{i,t}\right)^{\beta^T} \left(\hat{p}_{i,t}^T\right)^{1-\beta^T} \hat{d}_{ni,t} \hat{\tau}_{ni,t} \right)^{-\theta} \right)^{-1/\theta}, \tag{14}$$

$$\hat{p}_{n,t} = \left(\hat{p}_{n,t}^T\right)^{\alpha} \left(\hat{w}_{n,t}\right)^{(1-\alpha)} \left(\hat{A}_{n,t}\right)^{-(1-\alpha)/\beta^{NT}}, \tag{15}$$

$$\hat{\pi}_{ni,t} = \hat{T}_{i,t} \left(\frac{\left(\hat{w}_{i,t}\right)^{\beta^T} \left(\hat{p}_{i,t}^T\right)^{1-\beta^T} \hat{d}_{ni,t} \hat{\tau}_{ni,t}}{\hat{p}_{n,t}^T} \right)^{-\theta}, \tag{16}$$

$$X_{i,t}^T(s^t) \hat{X}_{i,t}^T = \alpha X_{i,t}(s^t) \hat{X}_{i,t} + \left(1 - \beta^T\right) \sum_{n=1}^N \pi_{ni,t}(s^t) \frac{X_{n,t}^T(s^t)}{\tau_{ni,t}(s^t)} \hat{\pi}_{ni,t} \frac{\hat{X}_{n,t}^T}{\hat{\tau}_{ni,t}}, \tag{17}$$

$$w_{i,t}(s^t) L_i \hat{w}_{i,t} = (1-\alpha) X_{i,t}(s^t) \hat{X}_{i,t} + \frac{\beta^T}{1-\beta^T} \left(X_{i,t}^T(s^t) \hat{X}_{i,t}^T - \alpha X_{i,t}(s^t) \hat{X}_{i,t} \right), \tag{18}$$

where $\hat{A}_{n,t}$ represents a productivity shock in the non-tradable sector. We condition the system on the data observed under the realized state history s^t:

$$\left\{w_{i,t}(s^t)L_i, X_{n,t}(s^t), X_{n,t}^T(s^t), \pi_{ni,t}(s^t), \tau_{ni,t}(s^t)\right\}_{i,n=1}^{N}.$$

In the next section, we describe how to take this extended model to the data, and how to use observed data in a given history s^t to compute counterfactual outcomes under an alternative history $\tilde{s}^t$.

3.2 Taking the Model to the Data

We now describe the data that we use for our quantitative analysis. Bilateral trade data comes from UN Comtrade for the year 2023, the latest available year. We compute tariff-inclusive bilateral spending on tradable goods, $X_{ni,t}^T$ for $n \neq i$, by incorporating the cost of tariffs into the Comtrade data. The tariff data needed to measure $\tau_{ni,t}$ come from the World Integrated Trade Solution (WITS). We use the most recent available effective tariff rate reported by WITS for each country, and use the MFN tariff when the effective rate is missing.

Data on production are sourced from the United Nations (UN), which reports value added for agriculture, mining, manufacturing, and utilities—grouped as the tradable sectors—and the rest of the economy, which we include in the non-tradable sector. Summing across tradable and non-tradable sectors and across countries we obtain global value added, VA_t. We obtain the share of value added in gross output for the tradable and non-tradable sectors, $\beta^T = 0.3131$ and $\beta^{NT} = 0.5715$, based on the ratio of global value added to global gross output, for each sector as reported in the World Input Output Database (WIOD). Given these value added shares, assumed to be constant across countries, we can back out gross output from value added for the tradable and non-tradable sectors. We compute domestic sales of tradables, $X_{nn,t}^T$, as the difference between gross output and country n's total exports. After data cleaning and consistency checks, we have data for $N = 187$ countries, including a residual rest of the world, which constitutes the sample for our quantitative analysis.

Total tradable spending of each destination country n is computed as the sum over its imports from each country:

$$X_{n,t}^T = \sum_{i=1}^{N} X_{ni,t}^T. \tag{19}$$

We can then compute the bilateral trade shares, $\pi_{ni,t}$, as the fraction of country n's spending on tradables that is allocated to imports from i:

$$\pi_{ni,t} = \frac{X_{ni,t}^T}{X_{n,t}^T}. \tag{20}$$

We calibrate the share of final spending allocated to tradables as:

$$\alpha = \frac{\sum_{i=1}^{N} X_{i,t}^T - (1-\beta^T) \sum_{i=1}^{N} \sum_{n=1}^{N} \frac{X_{ni,t}^T}{\tau_{ni,t}}}{VA_t + \sum_{i=1}^{N} \sum_{n=1}^{N} (\tau_{ni,t} - 1) \frac{X_{ni,t}^T}{\tau_{ni,t}}}. \tag{21}$$

Note that global final spending on tradables, the numerator, is the difference between observed tradable spending and spending on intermediates. The denominator is global income, including tariff revenue. We end up with a value of $\alpha = 0.322$. Given α, we compute each country's total spending as:

$$X_{i,t} = \frac{X_{i,t}^T - (1-\beta^T) \sum_{n=1}^{N} \frac{X_{ni,t}^T}{\tau_{ni,t}}}{\alpha}. \tag{22}$$

Summing across counties gives us nominal global spending, $X_t = 106.6$ trillion USD in the year 2023. We use this value to deflate all other nominal values in the model, in line with our choice of the numeraire. Using the budget constraint implied by national income accounting, each country's total value added is given by:

$$w_{i,t} L_{i,t} = (1-\alpha) X_{i,t} + \beta^T \sum_{n=1}^{N} \frac{X_{ni,t}^T}{\tau_{ni,t}}, \tag{23}$$

Finally, we calibrate two key parameters based on standard values from the literature. We set the trade elasticity to $\theta = 4$ (see Simonovska and Waugh (2014) and Caliendo and Parro (2015)). This parameter governs the sensitivity of trade flows to changes in trade costs and influences the degree of trade reallocation. We set the coefficient of relative risk aversion to $\gamma = 2$, which is near the median of the range of existing estimates (see Elminejad et al. (2025)). This parameter determines the curvature of the utility function and the strength of consumption smoothing in response to uncertainty.

We now turn to a quantitative analysis of how a shock to tariffs impacts spending, income, trade imbalances, prices, and real consumption.

3.3 Tariff Counterfactuals

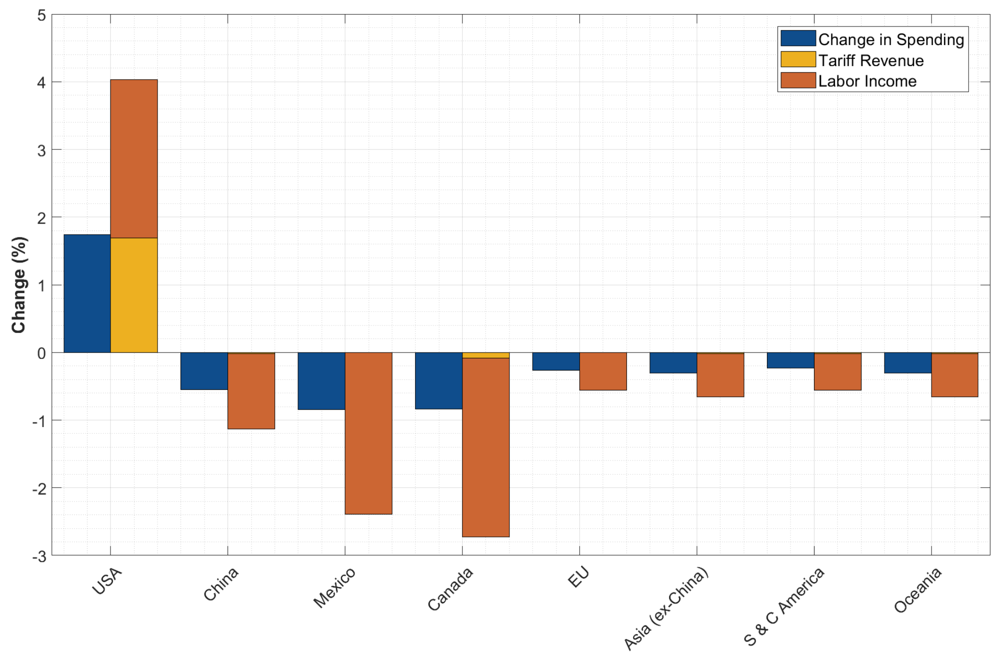
We now utilize the framework laid out in previous sections to analyze how equilibrium allocations at time t would change if, instead of the event s_t, an alternative event $\tilde{s}_t$ occurs. In particular, we define s_t as the event without a tariff shock, while $\tilde{s}_t$ represents the event of a tariff shock (recall that these events are the final entries in the histories s^t and $\tilde{s}^t$).

We start by analyzing the counterfactual scenario in which $\tau_{USA,i}(\tilde{s}^t) = \tau_{USA,i}(s^t) + 0.1$, except when i is China in which case $\tau_{USA,i}(\tilde{s}^t) = \tau_{USA,i}(s^t) + 0.3$. Specifically, the U.S. tariffs applied to China increase by 30 percentage points and the U.S. tariffs applied to every other country in the world increase by 10 percentage points.

Figure 1 illustrates changes in income and spending in the United States, China, and other countries and regions worldwide. The event of an increase in U.S. tariffs leads to an increase in U.S. income (relative to global income), driven by a significant rise in both wages and tariff revenues, as indicated by the colors in the right-hand bars in the figure. Conversely, the shock to tariffs causes a decline in income shares in other countries and regions, mainly due to terms-of-trade effects, reflected in lower wages in countries other than the United States.

The darker bars on the left in Figure 1 illustrate the percentage change in spending (relative to global spending) across countries and regions. The United States experiences an increase in spending, while other countries and regions see a reduction. Importantly, changes in spending across countries are less pronounced than changes in income. This pattern reflects the role of international assets, which allow countries to smooth consumption in the face of shocks. The eight figures in Appendix A.1, show that the same pattern applies to individual countries within different regions of the world.

Figure 1: Change in Income and Spending

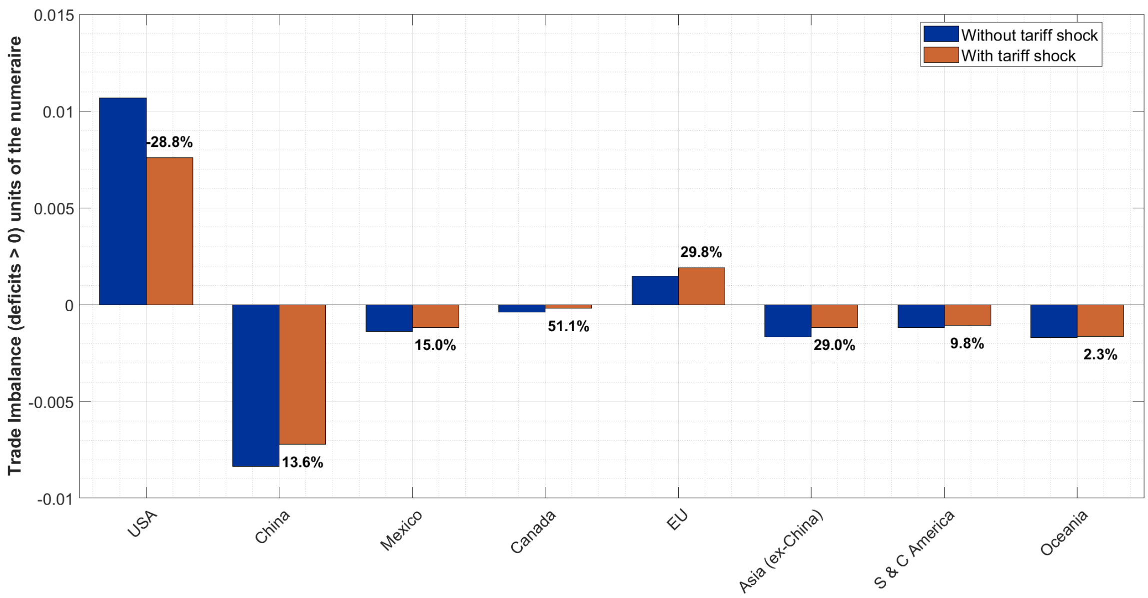


Note: The figure shows the percentage change in spending and income across different countries and regions in the world, in the tariff counterfactual where U.S. tariffs increase by 30 percentage points for China and 10 percentage points for all other countries. The change in spending is displayed by the darker bars on the left. The change in income is displayed by the lighter bars on the right, decomposed along the lines of equation 1. The darker portion of each bar on the right shows the change in income due to the change in labor income, while the lighter portion shows the change in income due to the change in tariff revenues.

Figure 2 displays trade imbalances across countries in both states of the world. Due the to tariff shock, countries experiencing an income rise, such as the United States, use assets to smooth consumption which results in a smaller deficit than in the baseline scenario with no tariff shock. The opposite occurs in countries where income declines. This logic explains the movements in trade imbalances due to the tariff shock.

As we saw in Figure 2, the tariff shock generates a decline in the trade deficit of the United States. At the same time, there is a reduction in trade surpluses in other countries and regions of the world. These changes in deficits have a bilateral component. Figure 3 shows that the decline in the overall U.S. trade deficit reflects a broad narrowing of its bilateral deficits. For instance, the U.S. trade deficits with China and Mexico shrink by more than a third; deficits with Europe, Asia, and Latin American countries decline by about one-third; and the deficit with Canada, which falls the most

Figure 2: Trade Imbalances



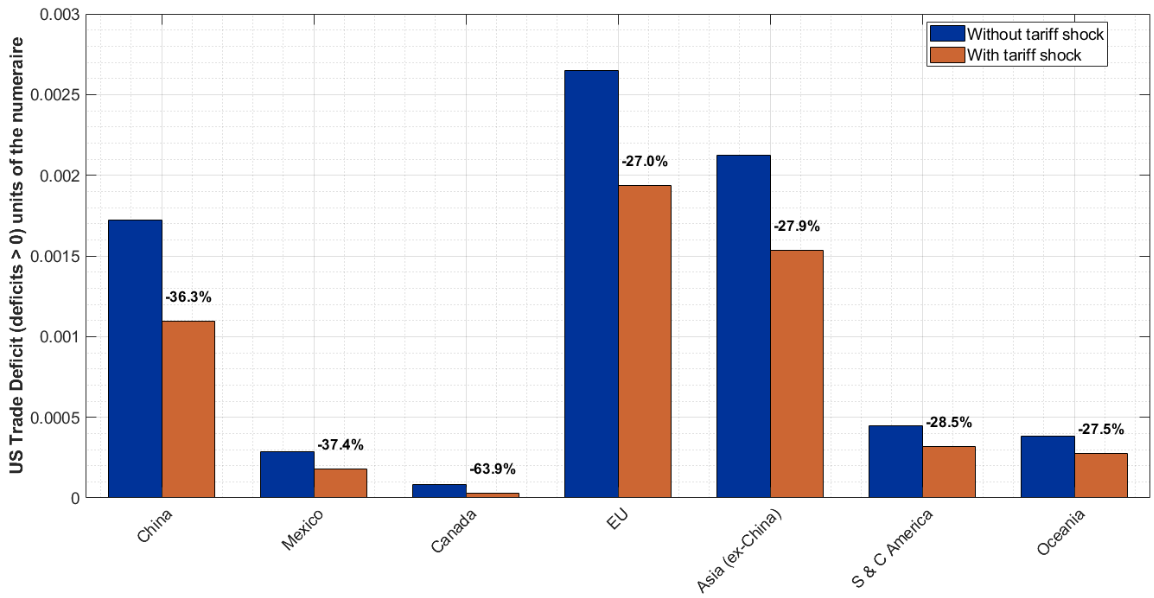
Note: The figure shows trade imbalances, measured relative to global spending, across countries and regions in the baseline (left hand side bars) and under a counterfactual where U.S. tariffs rise by 30 percentage points on China and 10 points on all others (right hand side bars). Trade imbalances are defined as spending minus income. The number next to the right hand bars represent the percentage change relative to the baseline.

in percentage terms, nearly disappears.

Figure 4 reports changes in the price level (again relative to global spending) across countries and regions following the U.S. tariff shock . Prices rise in the United States and fall elsewhere. The increase in U.S. prices reflects the direct effect of higher tariffs on import prices, and the indirect effect of higher U.S. wages on non-tradable goods prices and domestically produced tradable goods prices. In contrast, price levels decline in other countries and regions due to lower global demand and consequently lower wages. These regional price levels are aggregated using expenditure weights. The asymmetry highlights how unilateral tariff increases can induce global relative price adjustments through general equilibrium channels.

Figure 5 presents the percentage change in real consumption (calculated as the ratio of nominal spending to the price level) across countries and regions under the tariff counterfactual. In the United States, real consumption declines by 1.78 percent. Although nominal income increases due to higher tariff revenues, final spending rises

Figure 3: U.S. Bilateral Trade Imbalances



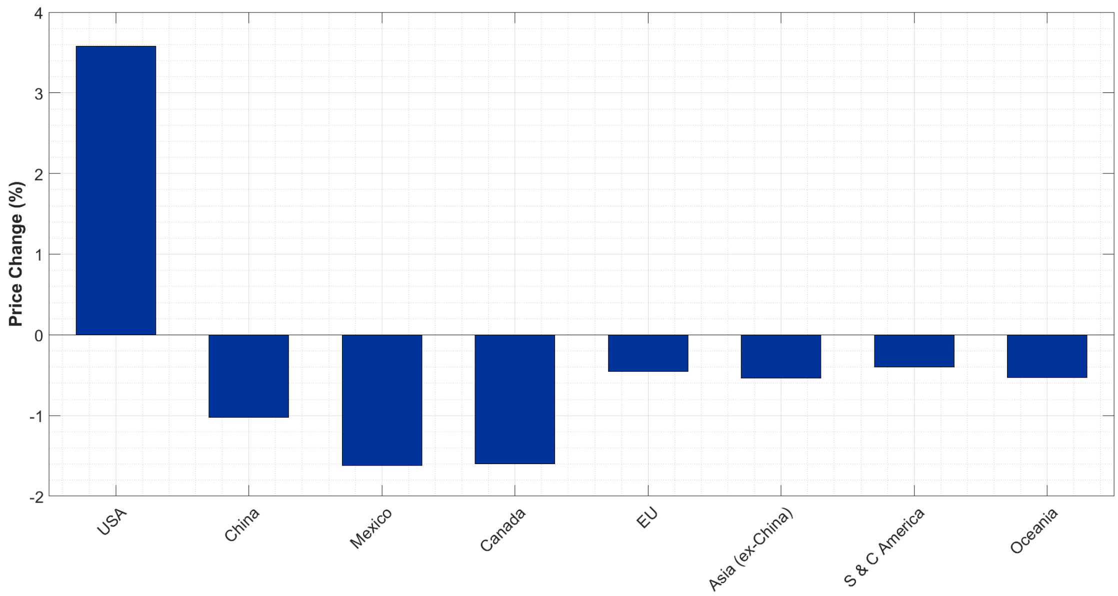
Note: The figure shows the U.S. bilateral trade imbalances, measured relative to global spending, across countries and regions in the baseline (left hand side bars) and under a counterfactual where U.S. tariffs rise by 30 percentage points on China and 10 points on all others (right hand side bars). Trade imbalances are defined as imports minus exports. The number next to the right hand bars represent the percentage change relative to the baseline.

less. The associated rise in the domestic price index more than offsets these gains, resulting in lower consumption in real terms.

In contrast, many surplus countries—including China, Mexico, Canada, and others—experience increases in real consumption despite facing declines in income. These countries start with trade surpluses in the baseline scenario. As tariffs reduce their export revenue, they respond by narrowing their surpluses or even running small deficits, effectively reallocating spending across states. This intertemporal adjustment allows them to sustain or even raise current consumption levels. The additional spending more than offsets the income loss, resulting in a net gain in real consumption. Hence, while the United States suffers a decline in real purchasing power, surplus countries increase their purchasing power from the adjustment in trade imbalances triggered by the tariff shock.

Taken together, Figures 1 through 5 illustrate the key economic forces that drive outcomes in the tariff counterfactual. The increase in tariffs raises U.S. income directly

Figure 4: Change in Prices

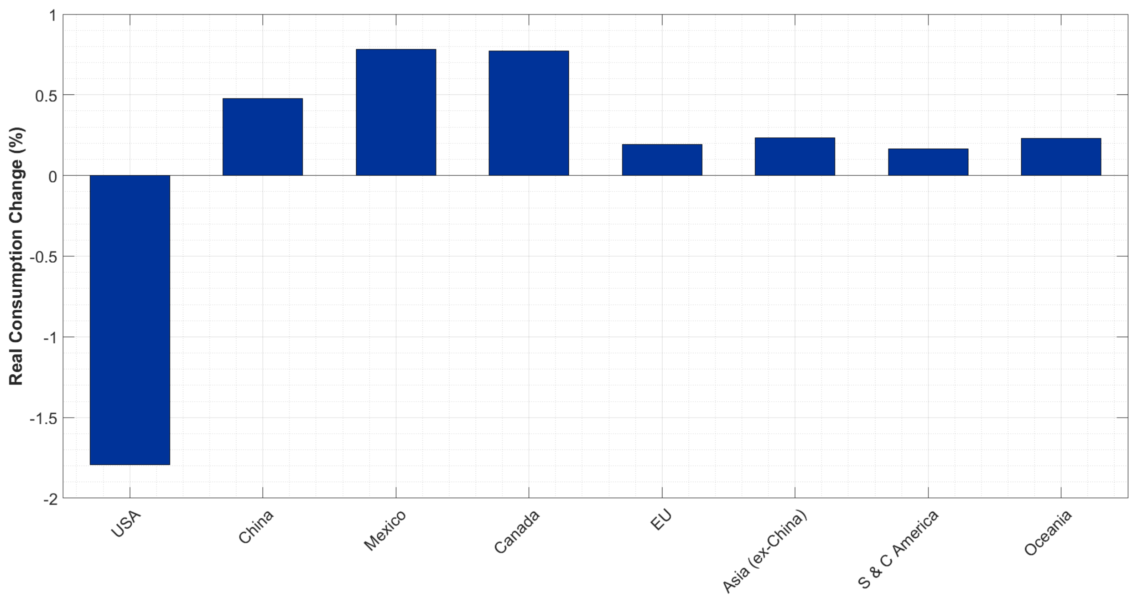


Note: The figure shows the percentage change in price levels across countries and regions of the world in the tariff counterfactual, where U.S. tariffs rise by 30 percentage points on China and 10 points on all others, relative to the observed equilibrium. Price levels across countries within a given region are aggregated using expenditure weights.

through tariff revenue and indirectly through a higher wage for labor. Due to complete asset markets this higher income doesn't translate into equally higher spending, hence the U.S. trade deficit declines. Since tariffs also raise domestic prices, real consumption falls. Other countries experience income losses but adjust their trade imbalances to support consumption, resulting in real consumption gains for many surplus economies. The tariff shock reshuffles global trade patterns, narrows U.S. bilateral deficits with key partners, and generates asymmetric price and consumption effects across regions, with the United States bearing the real economic cost of its protectionist tariffs.

We now turn to a second tariff counterfactual based on the schedule announced by the United States on April 2, 2025—the *Liberation Day tariffs*. In this scenario, we analyze the effects of a state $\tilde{s}_t$ characterized by the implementation of the announced tariff formula:

Figure 5: Change in Real Consumption



Note: The figure shows the percentage change in real consumption across countries and regions of the world in the tariff counterfactual, where U.S. tariffs rise by 30 percentage points on China and 10 points on all others, relative to the observed equilibrium. Real consumption is computed as the change in spending divided by the country's price level, and prices are aggregated across countries within a given region using expenditure weights.

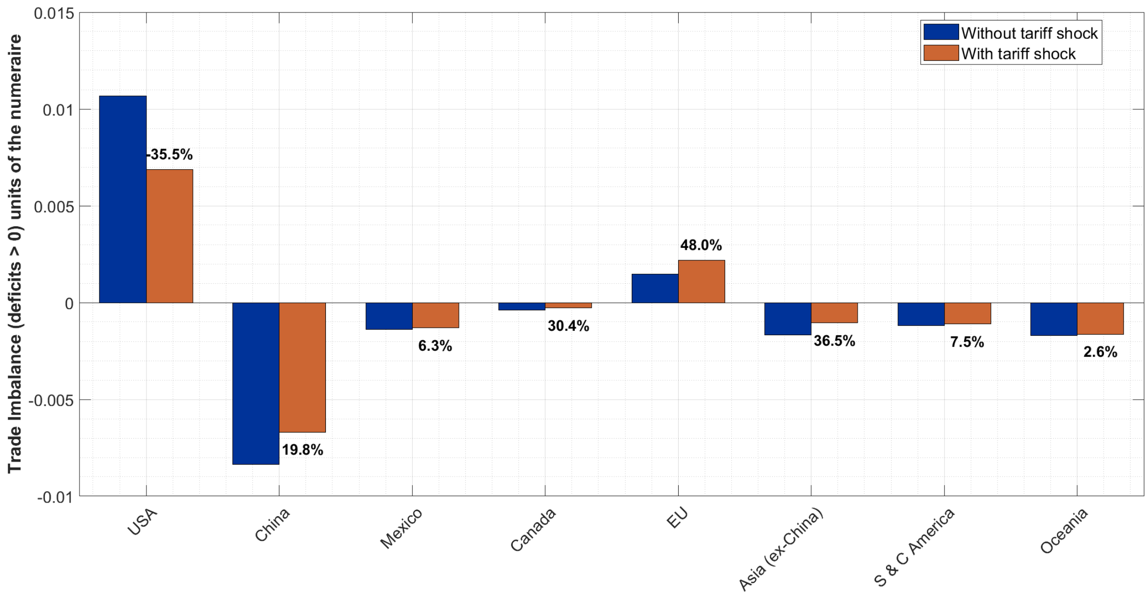
$$\tau_{USA,i}(\tilde{s}^t) = \tau_{USA,i}(s^t) + \max\{\frac{1}{2}\frac{D_{USA,i}}{X_{USA,i}}, 0.1\}. \tag{24}$$

That is, the United States raises its tariff on each country by the larger of 10 percentage points or half the bilateral deficit-to-imports ratio. We apply this formula to our 2023 data to compute the implied tariff changes and analyze their effects.[13]

Figure 6 reports trade imbalances across countries and regions before and after the Liberation Day tariffs. The U.S. trade deficit declines by slightly more than 35 percent (although it remains large relative to other countries) reflecting the broad-based increase in tariffs and the associated general equilibrium adjustments in income and spending. Most countries with initial trade surpluses—such as China, Mexico, and Canada—exhibit smaller changes in their external positions. In contrast, Europe ex-

[13]The two figures in Appendix A.2 show results based on the actual tariff schedule announced on April 2, 2025, which was constructed using the same formula (24) but with different trade data. These figures are consistent with, and reinforce, the findings presented below.

Figure 6: Trade Imbalances - Liberation Day tariff counterfactual

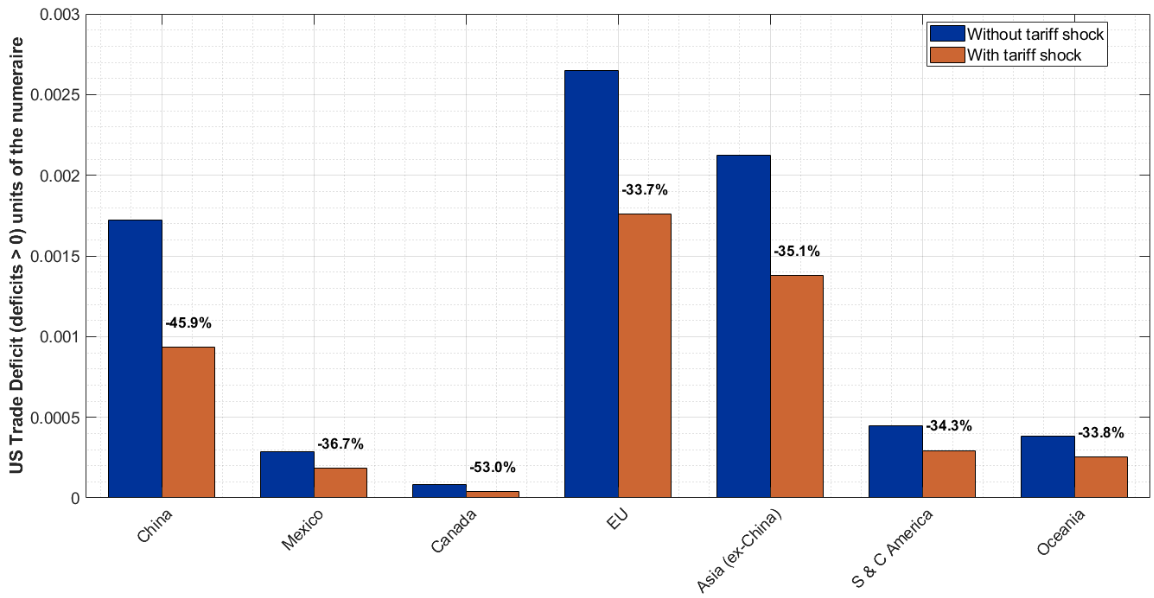


Note: The figure shows trade imbalances, measured relative to global spending, across countries and regions in the baseline (left hand side bars) and under a tariff counterfactual where the U.S. imposes the changes in tariffs announced on April 2, 2025. We applied the formula used to compute these tariff changes to the countries on which the U.S. imposed them, as described in Section 3.3, using the data presented in Section 3.2. The number next to the right hand bars represent the percentage change relative to the baseline.

periences a notable widening of its trade deficit, reflecting a sharp drop in European exports to the United States, which is not fully offset by exports to other countries. The pattern underscores the asymmetric effects of U.S. tariff increases and their role in redistributing trade imbalances across regions.

Figure 7 illustrates the U.S. bilateral trade imbalances before and after the Liberation Day tariffs. While overall deficits decline substantially, imbalances with major trading partners—including China, Mexico, and Canada—remain large in absolute terms. This result reflects the fact that, even after significant tariff adjustments, trade remains far from autarky and countries continue to reallocate resources intertemporally. As we have emphasized throughout, the presence of asset trade enables countries to smooth consumption in response to shocks, allowing imbalances to persist even under large tariff increases. The figure reinforces a central implication of the model: higher tariffs reshape the pattern and size of trade imbalances, but do not eliminate them.

Figure 7: Bilateral Trade Imbalances - Liberation Day tariff counterfactual



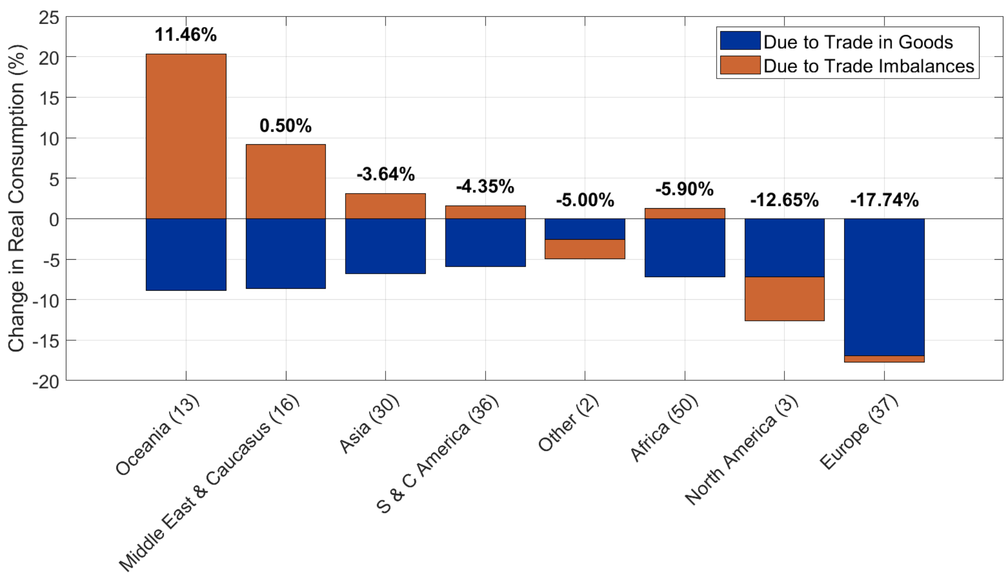
Note: The figure shows the U.S. bilateral trade imbalances, measured relative to global spending, across countries and regions in the baseline (left hand side bars) and under a counterfactual where the U.S. imposes the changes in tariffs announced on April 2, 2025. We applied the formula used to compute these tariff changes to the countries on which the U.S. imposed them, as described in Section 3.3, using the data presented in Section 3.2. Trade imbalances are defined as imports minus exports. The number next to the right hand bars represent the percentage change relative to the baseline.

Taken together, Figures 6 and 7 highlight the distributional consequences of the Liberation Day tariff schedule on global trade imbalances. The U.S. trade deficit contracts, with the largest bilateral adjustments occurring with its main trading partners—China, Mexico, and Canada. Despite the reductions, tariff shocks reallocate, but do not eliminate, trade imbalances. The tariff shock imposes a significant domestic cost: U.S. prices rise by 4.40 percent, and real consumption declines by 2.72 percent, as the inflationary impact of the tariffs outweighs the increase in nominal spending.

3.4 Autarky Counterfactual

We now turn to our most extreme counterfactual, going to autarky, in which trade imbalances surely vanish. We focus on the change in real consumption, computed as the ratio of the counterfactual level of consumption in autarky to the observed level of consumption.[14] Figure 8 displays these results as percentage changes in real consumption for different regions around the world. Specifically, the darker bars display the static losses from eliminating trade in goods, while the lighter bars show the ex-post single-period gains or losses from eliminating trade imbalances. As expected, real consumption declines in each region under prohibitive tariffs (equivalently, prohibitive trade costs), as countries lose the traditional gains from Ricardian specialization. In contrast, the effects of shutting down trade imbalances—i.e., asset trade—can be positive or negative: countries with initial trade deficits lose the additional consumption they could finance through asset trade in the open economy, while countries starting from trade surpluses benefit, since in autarky less of their income is used to finance consumption abroad.

Figure 8: Change in Real Consumption under Autarky



Note: The figure shows the percentage change in real consumption in autarky relative to the observed equilibrium, computed using equation (25) from footnote 14. The darker portion of each bar (in blue) shows the percentage change in real consumption due to trade in goods, given by the first term in (25), and the lighter portion (in red) shows the change due to trade in assets, given by the second term in (25). The numbers above each bar represent the net effect on real consumption.

[14] We use a variant of equation (11):

$$\frac{\hat{X}_{n,t}}{\hat{p}_{n,t}} = \pi_{nn,t}(s^t)^{\alpha/(\theta\beta^T)} \left(\frac{w_{n,t}(s^t)L_n}{X_{n,t}(s^t)}\right). \tag{25}$$

The derivation follows the one in footnote 12 except that, due to intermediates, the inversion yields $\hat{w}_{n,t}/\hat{p}^T_{n,t} = \pi_{nn,t}(s^t)^{1/(\theta\beta^T)}$ and due to nontradables, $\hat{w}_{n,t}/\hat{p}_{n,t} = \left(\hat{w}_{n,t}/\hat{p}^T_{n,t}\right)^{\alpha} = \pi_{nn,t}(s^t)^{\alpha/(\theta\beta^T)}$.

The numerical magnitudes labeled in Figure 8 are the net effect on real consumption from transitioning to a state with no goods trade and no trade imbalances. Oceania—the first bar—comprises 13 countries, with the results largely reflecting Australia. The region loses static gains from trade, which are more than offset by the gains from no longer running a large trade surplus, leading to a net gain of nearly 11 percent. North America—the second-to-last bar, largely reflecting the United States—loses both the static gains from trade and the consumption previously financed by its trade deficit, for a net loss exceeding 12 percent in terms of real consumption.

4 Conclusion

This paper has developed a framework for analyzing the effects of aggregate shocks in quantitative multi-country trade models with endogenous trade imbalances. By incorporating Arrow securities into such a model, we show that trade deficits emerge as optimal responses to state-contingent shocks, including uncertain changes in tariffs. Our framework represents a key departure from most quantitative trade models, that typically assume either trade balance or exogenous trade deficits.

The paper also extends the exact-hat-algebra methodology to dynamic environments with uncertainty, enabling counterfactual analysis in such settings. We use this model and method to study the effects of tariff shocks.

The quantitative analysis reveals striking results about the effects of recent and proposed U.S. tariff shocks. Our simulations of both hypothetical tariff scenarios and the Liberation Day tariff schedule announced in April 2025 consistently show that U.S. tariff increases lead to reductions in the U.S. trade deficit. Importantly, this reduction doesn't happen through simple arithmetic—fewer imports minus unchanged exports. Instead, it occurs through general equilibrium adjustments in income, spending, and optimal asset positions. Specifically, we find that targeted tariffs on China combined with broader tariff increases reduce U.S. bilateral deficits with major trading partners by one-third to one-half.

However, these changes in trade balances come at a significant cost. Despite higher income from tariff revenues, the United States experiences a decline in real consumption due to higher domestic prices. This finding underscores a fundamental tension from recent proposed and actual increases in U.S. tariffs: while tariffs may partly achieve the stated objective of reducing trade deficits, they simultaneously erode the real purchasing power of domestic consumers.

Our results also illuminate the global spillover effects of U.S. tariff increases. Countries initially running trade surpluses may actually benefit in real terms from such tariff changes. These countries optimally reduce their surpluses (or increase their deficits) relative to baseline to smooth consumption in response to income declines, leading to real consumption gains. This finding suggests that the burden of protectionist policies may fall disproportionately on the implementing country rather than its trading partners.

We decompose the real consumption effects of trade into static gains from goods trade and dynamic effects of imbalances. Our autarky counterfactual reveals that both components are quantitatively important, with the intertemporal dimension providing significant departures from the traditional gains from trade.

While our analysis is not normative, it still has relevance for policy. Policymakers should recognize that trade deficits are not inherently problematic when they reflect optimal intertemporal allocation decisions in an uncertain world. Attempts to reduce trade deficits through tariffs impact real consumption by interfering with both efficient specialization in production and efficient risk-sharing arrangements. Therefore, the effectiveness of tariffs in achieving trade balance objectives must be weighed against their cost.

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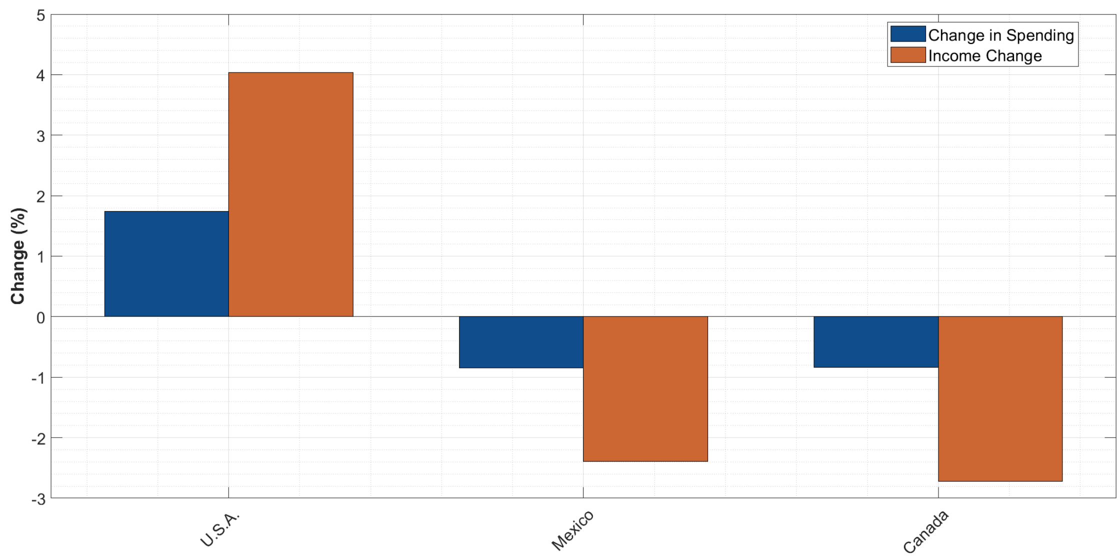
A Additional Results

A.1 Changes in Income and Spending Across Countries

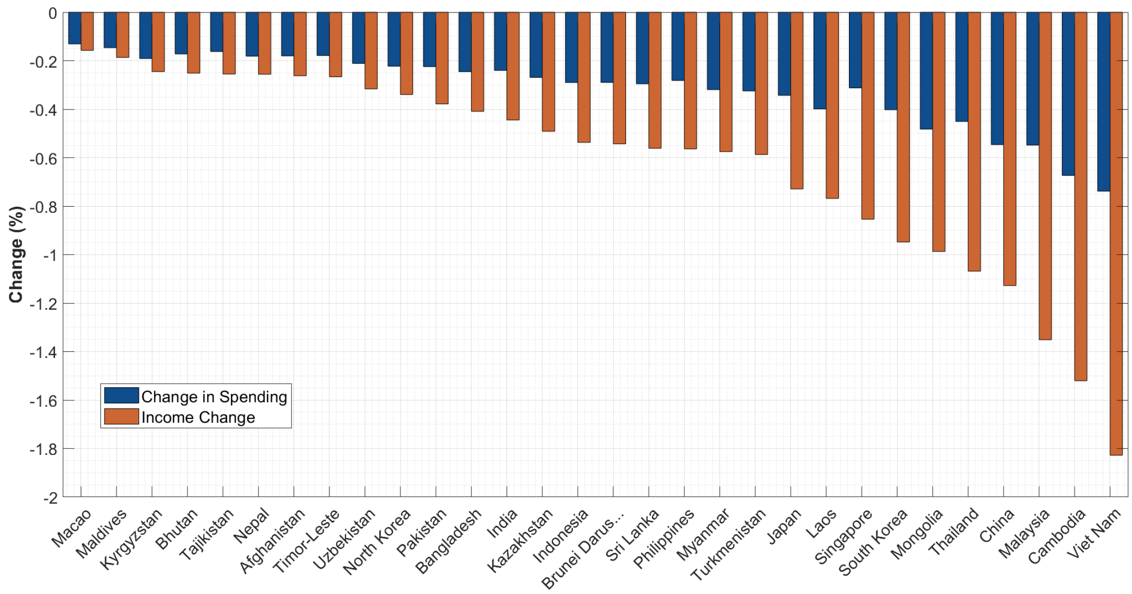
In this section of the appendix, we present the changes in income and spending across individual countries as a result of a tariff shock that increases the tariff applied by the U.S. to China by 30 percentage points and the tariffs applied to the other countries in the world by 10 percentage points.

Figure A.1: Change in Income and Spending in North America



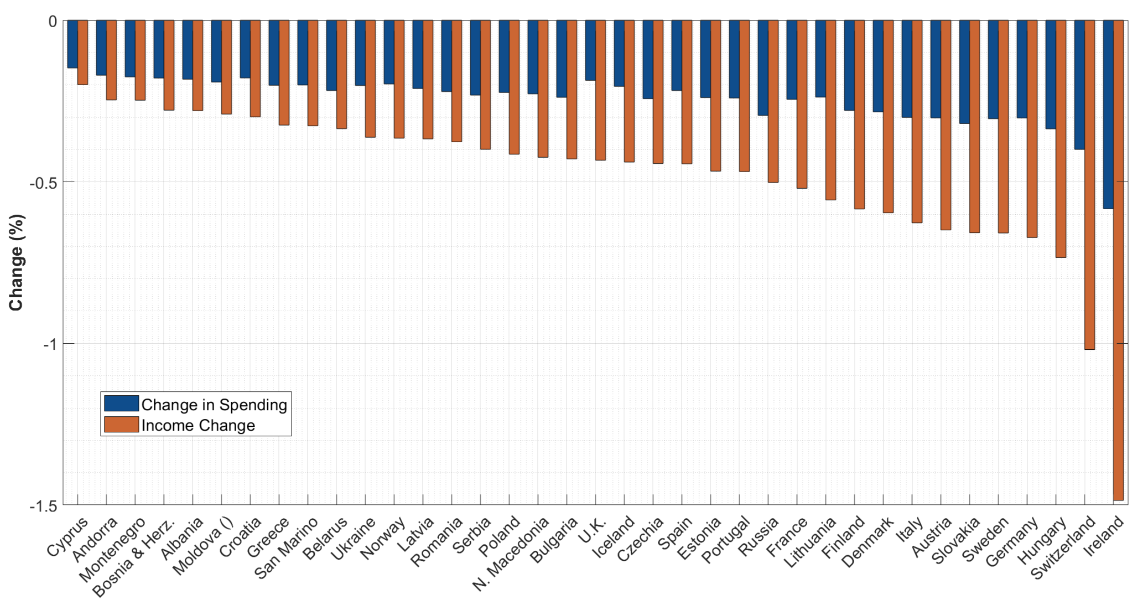
Note: The figure shows the percentage change, in the tariff counterfactual relative to the observed equilibrium, in aggregate spending and aggregate income across countries in North America.

Figure A.2: Change in Income and Spending in Asia



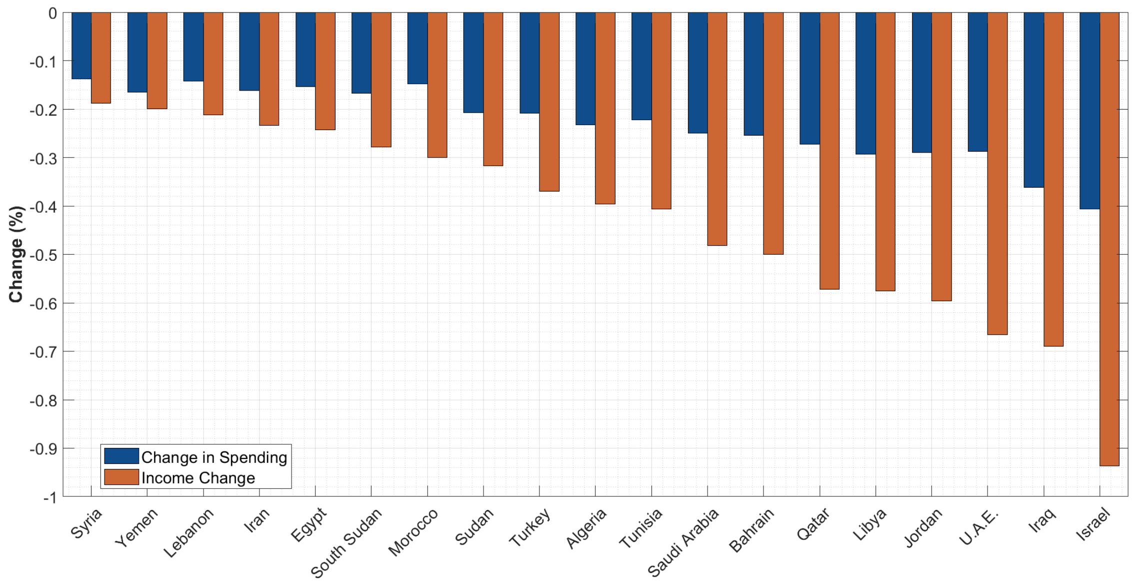
Note: The figure shows the percentage change, in the tariff counterfactual relative to the observed equilibrium, in aggregate spending and aggregate income across countries in Asia.

Figure A.3: Change in Income and Spending in Europe



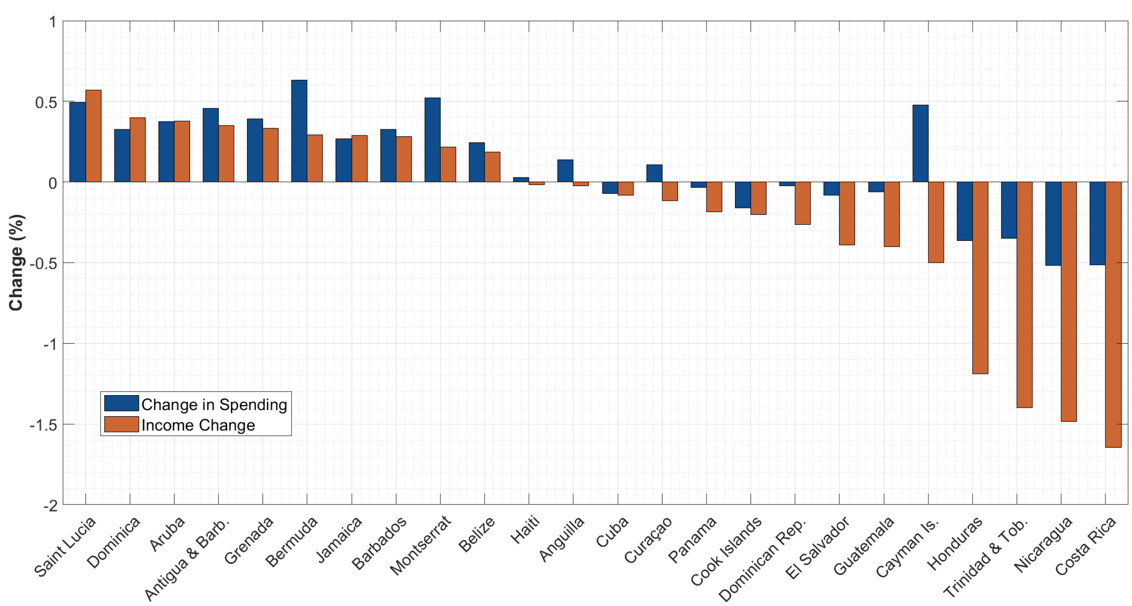
Note: The figure shows the percentage change, in the tariff counterfactual relative to the observed equilibrium, in aggregate spending and aggregate income across countries in Europe.

Figure A.4: Chng. in Income and Spending in the Middle-East and Africa



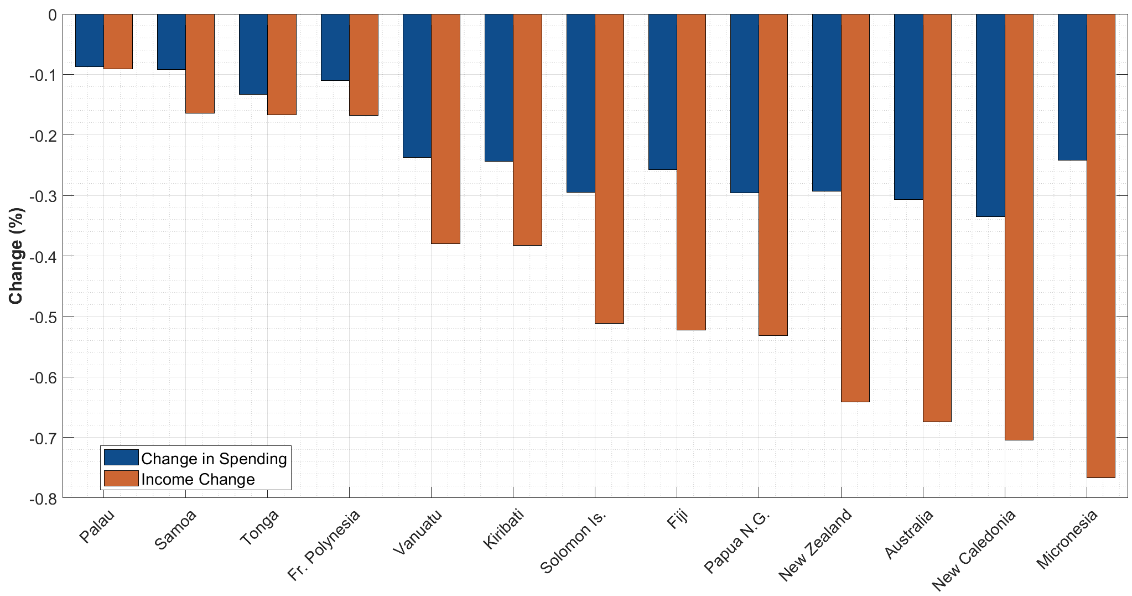
Note: The figure shows the percentage change, in the tariff counterfactual relative to the observed equilibrium, in aggregate spending and aggregate income across countries in the Middle East and North Africa.

Figure A.5: Change in Income and Spending in the Caribbean



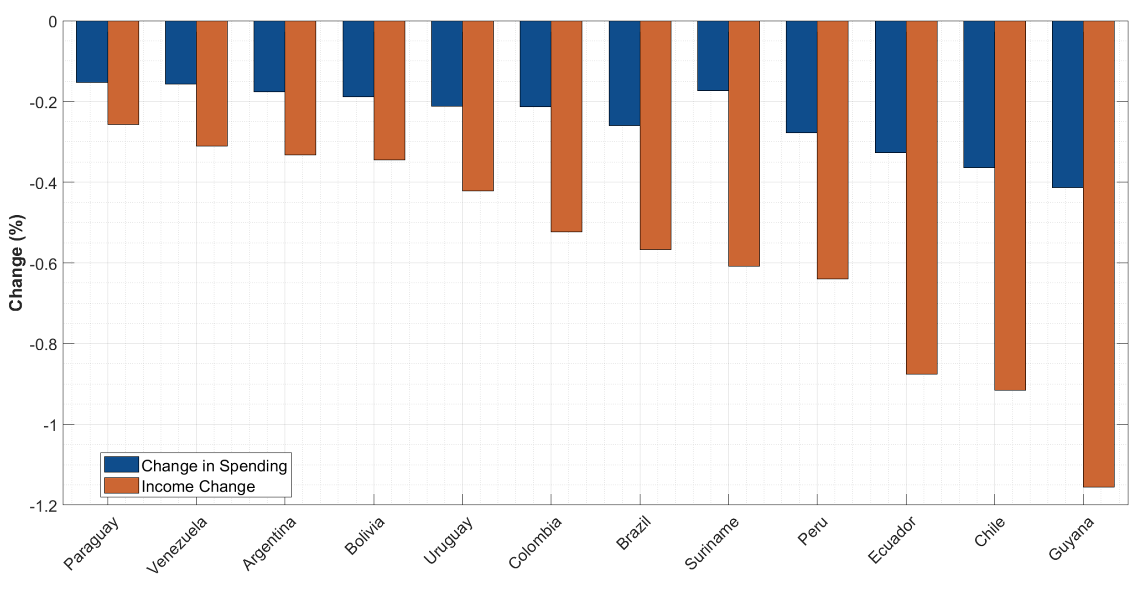
Note: The figure shows the percentage change, in the tariff counterfactual relative to the observed equilibrium, in aggregate spending and aggregate income across countries in the Caribbean.

Figure A.6: Change in Income and Spending in Oceania



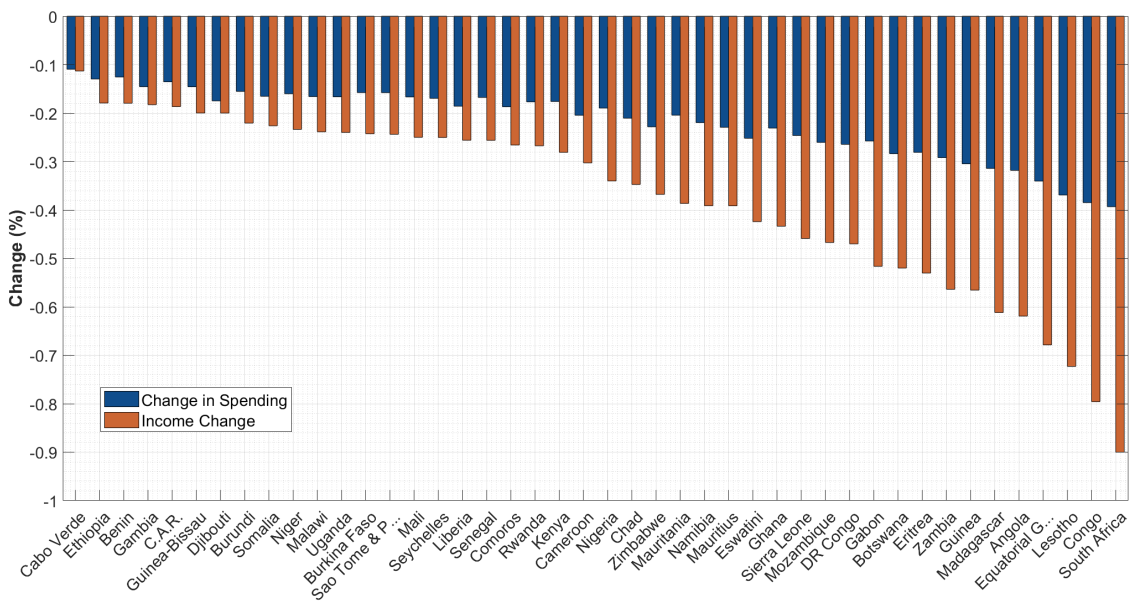
Note: The figure shows the percentage change, in the tariff counterfactual relative to the observed equilibrium, in aggregate spending and aggregate income across countries in Oceania.

Figure A.7: Change in Income and Spending in South America



Note: The figure shows the percentage change, in the tariff counterfactual relative to the observed equilibrium, in aggregate spending and aggregate income across countries in South America.

Figure A.8: Change in Income and Spending in Sub-Sahara Africa

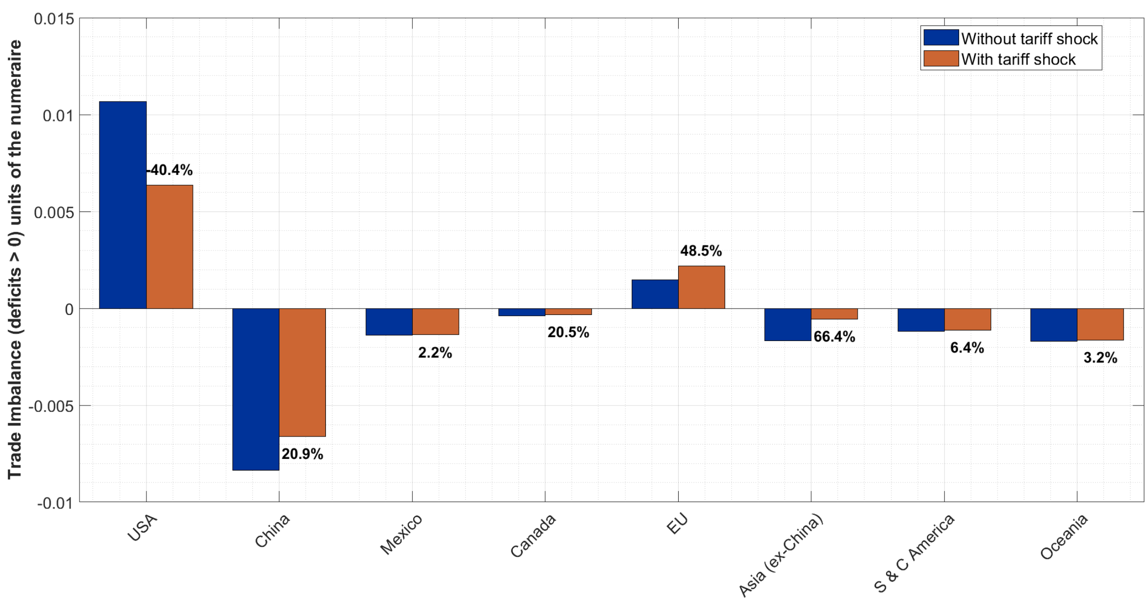


Note: The figure shows the percentage change, in the tariff counterfactual relative to the observed equilibrium, in aggregate spending and aggregate income across countries in Sub-Saharan Africa.

A.2 Changes in Trade Imbalances due to Liberation Day Tariffs

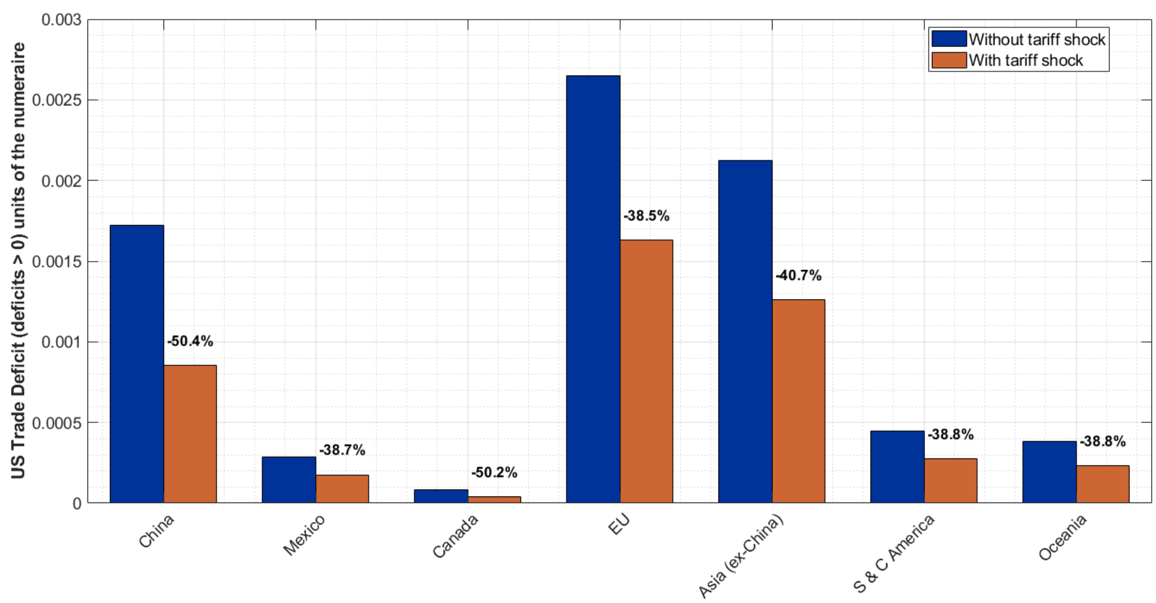
In this section of the appendix, we present the changes in trade imbalances resulting from the Liberation Day tariff changes announced on April 2, 2025, using the tariff changes announced that day. Figure A.9 shows the changes in trade imbalances for the United States and other countries and regions around the world, while Figure A.10 shows the changes in bilateral U.S. trade deficits.

Figure A.9: Trade Imbalances - Liberation Day tariff counterfactual



Note: The figure shows the percentage change in trade imbalances across different countries and regions of the world in the tariff counterfactual relative to the observed equilibrium. The tariff counterfactual imposes the changes in tariffs announced on April 2, 2025.

Figure A.10: U.S. Bilateral Imbalances - Liberation Day tariff counterfactual



Note: The figure shows the percentage change in U.S. bilateral trade imbalances across different countries and regions of the world in the tariff counterfactual relative to the observed equilibrium. The tariff counterfactual imposes the changes in tariffs announced on April 2, 2025.