

A World Trading System For Whom? Evidence from Global Tariffs*

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Abstract

We use global tariffs to reveal the weights that nations implicitly place on the welfare of their trading partners relative to their own. Our estimated welfare weights suggest that formal and informal rules of the world trading system make countries internalize the impact of their policies onto others to a substantial extent, though not fully. On average, countries place 19% less value on transfers to foreigners than transfers to their own residents. Across nations, we find that countries that put more weights on the welfare of foreigners also tends to receive higher welfare weights from them. Our results are consistent with international cooperation being sustained by a general form of reciprocity among nations: cooperative behavior by one country, in the form of a higher welfare weight, is reciprocated with cooperative behavior by its partner, also in the form of a higher welfare weight. This is true both within and outside the World Trade Organization.

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1 Introduction

International cooperation is, ultimately, about countries internalizing the impact that their own policies impose on others. In this paper, we develop a new empirical strategy to estimate the extent to which they do.

Our basic idea is to use countries' tariff-setting choices to reveal the weights that they implicitly place on the welfare of each of their trading partners relative to their own. In practice, there are many institutional features of the world trading system, both formal and informal, that might give countries incentives to set their tariffs in a cooperative manner. Countries may choose low tariffs by fear of future retaliation, as in [Dixit \(1987\)](#) and [Maggi \(1999\)](#), or they may simply be constrained by GATT/WTO rules, as in [Bagwell and Staiger \(1999\)](#). The key advantage of our empirical strategy is that it does not require us to take a stand on the specific ways through which such considerations might shape international cooperation. If rules of the world trading system are completely ineffective, then we should observe that countries follow their own self-interest and put zero weight on the welfare of others. If instead these rules are successful in fostering cooperation, then we should observe that countries at least partly internalize the impact of their own policies on their trading partners and place non-zero weight on changes in their utilities.

To learn about how much countries value each other's welfare, we combine data on global tariffs with measures of the incidence of these tariffs on real incomes around the world. Intuitively, if imports of certain goods have disproportionately negative effects on real incomes in some countries, then a country imposing low tariffs on these goods reveals that, all else equal, it puts little weight, or perhaps even negative weight, on the welfare of these countries. We formalize this intuition via an optimal tariff formula that allows for "as-if" altruistic motives across countries.

According to this formula, optimal trade taxes can be decomposed into the sum of two terms: (i) a classical terms-of-trade manipulation motive; and (ii) a new altruistic motive. The altruistic motive is itself a weighted sum of the changes in real income around the world caused by import restrictions, with weights equal to the marginal utility of income that the country restricting imports assigns to each of its trading partners relative to itself. If there are no altruistic motives, the tariffs predicted by our formula coincide with those of a one-shot Nash equilibrium. If all countries agree on the marginal utility of income that should be given to any country around the world, our formula describes the set of globally Pareto efficient tariffs. In between these extreme cases, our formula also applies to a wide class of dynamic tariff-setting games in which any one country's deviation from the welfare levels promised to trading partners along the equilibrium path can

trigger retaliation. Under this interpretation, welfare weights correspond to the Lagrange multipliers associated with each of these utility constraints.

From an empirical standpoint, our formula opens up the possibility of estimating the marginal value β_{ij} that a given country j assigns to the income of one of its trading partners i , relative to its own income, by running a simple linear regression whose dependent variable is the difference between country j 's observed tariff on a given good g and the opportunistic tariff predicted by the classical terms-of-trade manipulation motive and whose regressors are the changes in real income in different countries i caused by country j 's import restrictions of good g . To implement this strategy, we need data on global tariffs, estimates of opportunistic tariffs, and estimates of the welfare incidence of various import restrictions on the rest of the world. For global tariffs, we rely on the UNCTAD TRAINS database. Our baseline analysis focuses on 28 trading partners and 5,113 products in 2001, just as the phase-in of the tariff concessions from the WTO's last round of negotiations was approaching universal completion. For estimates of opportunistic tariffs and the incidence of import restrictions on foreign welfare, we develop a quantitative model of the world economy that extends [Fajgelbaum et al. \(2020\)](#) to a full global general equilibrium.

Our baseline estimates reveal that all of the countries in our sample internalize the impact of their policies onto others to a significant extent. The average value of β_{ij} that we estimate is 0.81. This implies that, for a typical importer, the value of one dollar transferred to another country is 19% lower than the value of that same dollar transferred to its own residents. The 10-90 range of our estimates is 0.62-0.98 and almost all of them are statistically significantly greater than the one-shot Nash value of zero. Yet, despite this widespread and generous as-if altruism, we do formally reject that the tariffs in our sample are set in a Pareto-efficient manner. This arises both because all countries tend to value themselves more than others—which is inconsistent with all countries agreeing on the marginal utility of income that should be given to any country around the world—and because countries miss collective opportunities to more efficiently redistribute income among others that they value less than themselves.

Turning to the cross-country variation in estimated welfare weights, our analysis reveals that “cooperative” countries, which put more weight on the welfare of foreigners, also tend to receive higher welfare weights from foreigners. This positive correlation between β_{ij} and β_{ji} suggests a general form of reciprocity à la [Axelrod \(1984\)](#) within the world trading system: cooperative behavior by one country, in the form of a higher welfare weight, is reciprocated with cooperative behavior by its partner, also in the form of higher welfare weight.

Interestingly, this general form of reciprocity, i.e., a tendency for the matrix of β_{ij} to be symmetric, is not predicted by canonical models of formal trade agreements. The seminal analysis of [Bagwell and Staiger \(1999\)](#), in particular, only provides conditions under which GATT/WTO rules induce $\beta_{ij} = 1$. As we document, this reciprocal pattern is also not a salient feature of raw tariff data, nor does it appear to be a manifestation of participation in formal trade agreements, either related to membership in the WTO or a Preferential Trade Agreement (PTA), since reciprocal behavior is evident even after conditioning on such participation. Reciprocity also holds conditional on exporter and importer fixed effects, and for most importers in specifications that allow each importer to have its own reciprocity coefficient, implying that even relatively selfish importers behave relatively generously towards those exporters that treat them generously in return.

These findings are robust to a number of departures from our baseline analysis. One examines tariffs over the full period 1997-2019. We find that the average value of β_{ij} rises over the period and that reciprocity is strong year by year as well as in changes over time (in a way that, like in the cross-section, raw tariffs are not). A second introduces multiple factors of production in our baseline model, thereby creating redistributive motives for trade protection within each country. The last extensions consider alternative calibrations of our model's key parameters. Despite the fact that opportunistic tariff levels are sensitive to these considerations, we show that our main findings are not.

The final part of our paper provides a first look at the potential gains from international cooperation via reciprocity. To do so, we treat the welfare weights as exogenous, an admittedly strong assumption, and ask for any given country, how its welfare would change if it stopped assigning non-zero welfare weights to others and others stopped reciprocating by assigning non-zero welfare weights to this country. We refer to each country's welfare loss from this counterfactual relative to one where it acts opportunistically and others do not retaliate as its "gain from reciprocity." Our results point towards gains from reciprocity on the order of 5.2% for the median country, or about four times the median country's gains from a move from the uncooperative Nash equilibrium to the equilibrium with observed tariffs.

Related Literature

To evaluate the consequences of international rules and institutions, trade economists typically proceed as follows. They start from a hypothetical world when such institutions are absent, solve for the "Nash" tariffs that countries would unilaterally choose if left unconstrained, and then characterize how the introduction of specific institutions, either

in the form of constraints on their strategy sets or repeated interactions, may lead to new policy choices and sustain international cooperation. [Bagwell and Staiger \(2002\)](#) offer an overview and various applications of this canonical approach.

In this paper, we propose instead to estimate directly the combined effect of these institutions on international cooperation, as measured by the extent to which each country internalizes the impact of its own policy on each of its trading partners, without making explicit assumptions about how different rules and institutions affect countries' strategic interactions. This general strategy is the global counterpart to the revealed preference approach that we have used in [Adao et al. \(2023\)](#) to estimate the determinants of redistributive trade protection within the United States. It has similar benefits, in terms of the robustness of our welfare weight estimates, and costs, in terms of ruling out counterfactual simulations where these weights may endogenously change.

Throughout our analysis, we assume that the impact of countries' tariffs onto their trading partners travels through changes in their terms of trade. This creates a direct relationship between our findings and prior evidence about the role played by terms-of-trade considerations, both when countries set their tariffs unilaterally ([Broda et al., 2008](#)) and when they negotiate them ([Bagwell and Staiger, 2011](#) and [Ludema and Mayda, 2013](#)). In their test of the classical optimal tariff motive, [Broda et al. \(2008\)](#) document that for a number of non-WTO countries, tariffs are positively correlated with the inverse of the foreign export supply elasticities that they have estimated. Although the sign of this correlation is qualitatively consistent with the classical optimal tariff motive, its magnitude is much smaller than what self-interested manipulation alone would predict. The perspective put forward by our paper is that the latter observation is informative about the extent to which countries happen to internalize terms-of-trade externalities and therefore cooperate with one another.¹

Our findings that cooperative behavior by one country, in the form of a higher welfare weight, is reciprocated with cooperative behavior by its partner, also in the form of a higher welfare weight, is consistent with the evidence from [Limao \(2006\)](#) about US tariff cuts during the Uruguay round. He documents that such tariff cuts were systematically larger on products exported by countries that had themselves offered larger tariff cuts. As

¹In estimating the welfare weights that various countries put on each other, our analysis also relates to recent work by [Kleinman et al. \(2024\)](#). They define two countries as "economic friends" if growth in one country raises real income in the other. Using the rise of China and technological improvements in air transportation as exogenous shifters, they then document that closer economic friends are more likely to become "political friends" in the sense of their UN votes being more aligned. Using the same terminology, one can view our paper as instead identifying two countries as "political friends" if trade policies chosen by one country tend to systematically benefit the other. We then use this new measure of "political friendship" to study the efficiency and redistributive properties of the world trading system.

alluded to before, we find that reciprocal behavior is far more apparent in our estimated welfare weights than in the raw tariff data.² We also find that it holds both among WTO countries and non-WTO countries who have never directly participated in such trade negotiations. This implies that the pattern of international cooperation via reciprocity that we document must reflect more than the impact of formal GATT/WTO rules.³

Finally, our analysis relates to quantitative work on the costs of trade wars and the benefits of trade talks, including [Perroni and Whalley \(2000\)](#) and [Ossa \(2014\)](#), the welfare and labor market consequences of specific WTO rules, as in [Bagwell et al. \(2021\)](#) and [Bown et al. \(2023\)](#), and the broader gains from international cooperation in [Ritel \(2024\)](#). Among the previous papers, our analysis is closely related [Ritel \(2024\)](#) who also introduces and estimates altruistic motives across countries. Although his paper and ours share a common starting point and similar objectives, they differ both in terms of their implementation and substantial findings. From a theoretical standpoint, we build our analysis around a general tariff formula with as-if altruistic motives, which, as we formally establish, can capture the impact of both formal and informal rules of the world trading system. From an empirical standpoint, we use granular tariff data to estimate welfare weights for more than 700 of importer-exporter pairs. This focus on pair-specific welfare weights is critical to uncover that international cooperation is sustained by a general form of reciprocity among nations as well as to identify the conditions under which it is more likely to emerge.⁴

2 Optimal Trade Taxes with As-If Altruism

The goal of this section is to characterize the structure of optimal trade taxes with as-if altruism across countries. As we will explain shortly, these motives can be interpreted as the reduced-form impact of formal constraints on the strategy sets faced by otherwise self-interested countries or as the reduced-form impact of the informal threats of punishment that they face in a dynamic game.

²In [Limao \(2006\)](#), the preferred estimates of the impact of foreign tariff cuts on US tariff cuts range from 0.014 to 0.018 for products not subject to Non-Tariff Barriers (NTBs). They are of the opposite signs for products subject to NTBs.

³We come back to this issue in greater detail in Section 4.3 where we compare our empirical results to the theoretical predictions of [Bagwell and Staiger \(1999\)](#) about the implications of reciprocal tariff negotiations.

⁴In using a quantitative model to shed light on the efficiency of the world trading system, our paper also bears some broad relation to the test of optimal international risk sharing developed by [Fitzgerald \(2012\)](#).

2.1 A General Neoclassical Environment

We consider a general neoclassical environment à la **Dixit and Norman (1980)**. There are multiple countries, indexed by either i or $j \in \mathcal{I}$, and multiple goods, indexed by $g \in \mathcal{G}$.⁵

Supply. In each origin country i , there is a representative firm with production set Y_i . Aggregate factor endowments in country i are implicitly embedded in Y_i . The firm chooses its net output vector $y_i \equiv \{y_{gi}\}$ to solve

$$\begin{aligned} \max_y p_i \cdot y \\ \text{subject to: } y \in Y_i, \end{aligned} \tag{1}$$

where $p_i \equiv \{p_{gi}\}$ denotes the vector of prices in country i and the dot product \cdot refers to the inner product, $p_i \cdot y = \sum_g p_{gi}y_g$. We let $r_i(p_i) \equiv \max\{p_i \cdot y | y \in Y_i\}$ denote the associated revenue function.

Demand. In each destination country j , there is a representative consumer with utility $u_j(c_j)$ that depends on her consumption vector $c_j \equiv \{c_{gj}\}$. The consumer chooses c_j to solve

$$\begin{aligned} \max_c u_j(c) \\ \text{subject to: } p_j \cdot c = r_j(p_j) + \tau_j, \end{aligned} \tag{2}$$

where τ_j denotes a lump-sum transfer from country j 's government. Below we let μ_j denote the Lagrange multiplier associated with her budget constraint and let $e_j(p_j, u) \equiv \min_c \{p_j \cdot c | u_j(c) \geq u\}$ denote her expenditure function.

Government. In each country j , the government may impose specific trade taxes $t_j \equiv \{t_{gj}\} \in \mathcal{T}_j$. Trade taxes create a wedge between the local prices $p_j \equiv \{p_{gj}\}$ and the world prices $p^w \equiv \{p_g^w\}$. For any good g traded between country j and the rest of the world,

$$p_{gj} = p_g^w + t_{gj}. \tag{3}$$

⁵In standard Arrow-Debreu fashion, we implicitly allow goods to be differentiated by their location of production and consumption. Consistent with this convention, the counterpart of a good g in our empirical analysis will be a triplet consisting of a product category, an origin country, and a destination country. We come back to this point in Section 3.

If country j imports good g , $t_{gj} \geq 0$ corresponds to an import tariff, while $t_{gj} \leq 0$ corresponds to an import subsidy. If country j exports good g , $t_{gj} \geq 0$ corresponds to an export subsidy, while $t_{gj} \leq 0$ corresponds to an export tax. Trade taxes on a given good g are either unrestricted, $t_{gj} \in \mathbb{R}$, or restricted to be zero, $t_{gj} \in \{0\}$. We let \mathcal{G}_j^T denote the set of goods that can be taxed in country j and assume that at least one good is excluded from \mathcal{G}_j^T . In our quantitative model, all goods exported by a given country j will be excluded.⁶ Government budget balance requires

$$t_j \cdot (c_j - y_j) = \tau_j + T_j, \quad (4)$$

with T_j the transfer received by country j from the rest of the world, expressed in units of the numeraire. Throughout our analysis, we treat T_j as an exogenous parameter whose only purpose is to rationalize observed trade imbalances. By definition, $\sum_{j \in \mathcal{I}} T_j = 0$.

Market clearing. Supply equals demand for all goods,

$$\sum_{i \in \mathcal{I}} c_i = \sum_{i \in \mathcal{I}} y_i. \quad (5)$$

Competitive Equilibrium. We are now ready to define a competitive equilibrium.

Definition 1. A competitive equilibrium with trade taxes $\{t_i\}$ is a vector of output $\{y_i\}$, consumption $\{c_i\}$, local prices $\{p_i\}$, world prices $\{p^w\}$, and transfers $\{\tau_i\}$ such that: (i) y_i solves (1); (ii) c_i solves (2); (iii) p_i and p^w satisfy (3); (iv) τ_i satisfies (4); and (v) all markets clear, as described in (5).

2.2 Definition of Optimal Trade Taxes with As-If Altruism

It is standard in the trade literature to model each country as choosing its own policy in order to maximize its own welfare, potentially subject to constraints imposed by the WTO or other international arrangements. The question of interest then is how different constraints map into different policy choices. We propose instead to remain agnostic about the specifics of these institutional constraints and focus attention on the extent to which these constraints are successful in making countries internalize the impact of their policies onto others.

⁶Anchoring trade taxes at zero for some goods implies that there is no indeterminacy in the optimal level of taxes.

Definition 2. In any country j , we say that the vector of trade taxes t_j is optimal with as-if altruism if there exists a vector of welfare weights $\{\lambda_{ij}\}$ such that t_j solves

$$\begin{aligned} \max_{t \in \mathcal{T}_j, \{u_i\}} \quad & u_j + \sum_{i \neq j} \lambda_{ij} u_i \\ \text{subject to:} \quad & \{u_i\} \in \mathcal{U}(t, t_{-j}), \end{aligned} \tag{6}$$

where $\mathcal{U}(t, t_{-j})$ is the set of utility profiles attainable in a competitive equilibrium with trade taxes (t, t_{-j}) and t_{-j} is the vector of trade taxes imposed by the rest of the world.

Definition 2 nests several important special cases from the existing literature.

Example 1: Nash Tariffs. If $\lambda_{ij} = 0$ for all $i \neq j$, then countries are purely opportunistic. In this situation, the trade taxes given by (6) coincide with the one-shot Nash equilibrium of the unconstrained tariff game between self-interested countries. This is the situation illustrated in Figure 1a.

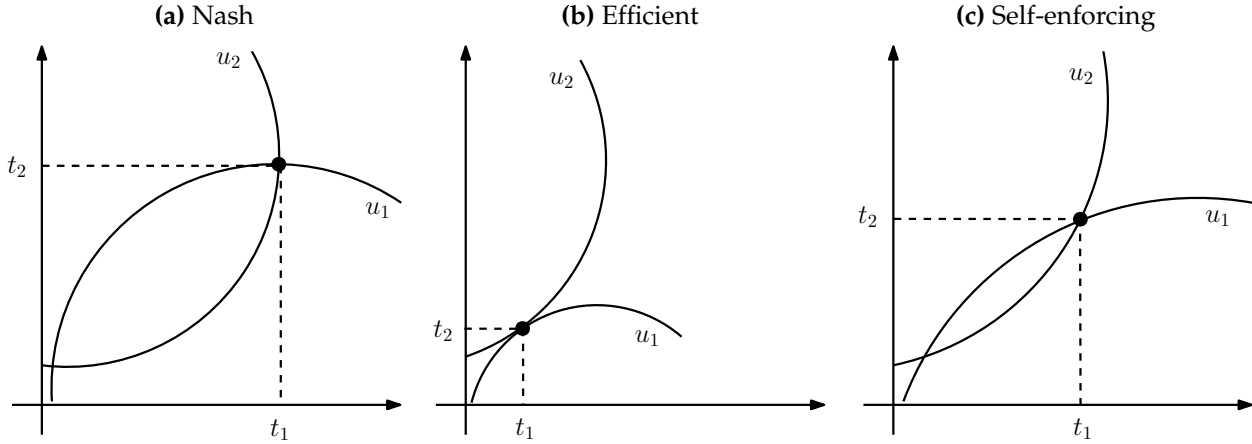
Example 2: Efficient Tariffs. If the welfare weights instead take the form $\lambda_{ij} = \lambda_i / \lambda_j > 0$ for some underlying vector $\lambda \equiv \{\lambda_j\} > 0$, then the trade taxes given by (6) instead coincide with a global Pareto optimum, in which tariffs $\{t_j\}$ maximize a common global welfare function, $\sum_j \lambda_j u_j$, as shown in Figure 1b.⁷ One particular point of interest along the global Pareto frontier is the one where the vector λ equalizes the social marginal utility of income across countries. As shown by Bagwell and Staiger (1999), it corresponds to the only Pareto optimum implementable when formal rules—akin to those imposed by the WTO—incentivize countries to ignore their ability to manipulate their terms of trade. We return to this important observation below.⁸

Example 3: Self-Enforcing Tariffs. Definition 2 applies more generally to self-enforcing tariffs in a dynamic environment. To see this, suppose that countries' tariffs in each year are their actions in a repeated game whose stage payoffs are determined by the economic environment described in Section 2.1. Suppose furthermore that the equilibrium of this

⁷Note that the set of global Pareto optima is the same regardless of whether one views the true preferences in country j as being given by u_j or $u_j + \sum_{i \neq j} \lambda_{ij} u_i$, i.e. regardless of whether one chooses to treat altruistic motives as “as-if” or not. This follows from the observation that if $\{t_j\}$ maximizes $\sum_j \lambda_j (u_j + \sum_{i \neq j} \lambda_{ij} u_i)$, then it also maximizes $\sum_j \tilde{\lambda}_j u_j$ with $\tilde{\lambda}_j \equiv \lambda_j + \sum_{i \neq j} \lambda_i \lambda_{ji}$.

⁸In between the two extreme cases described in examples 1 and 2, Definition 2 also captures situations where countries internalize the impact of their trade taxes on some, but not all of their trading partners. This may occur because only a subset of countries are able or willing to bargain over tariffs, say those that are part of the WTO, leading their tariffs $\{t_j\}_{j \in \text{WTO}}$ to maximize $\sum_{j \in \text{WTO}} \lambda_j u_j$.

Figure 1: Optimal Trade Taxes with As-If Altruism



Notes: This figure describes optimal trade taxes with as-if altruistic motives for two countries, $j = 1$ and $j = 2$, each of which taxes the imports of a single good. The two curves represent combinations of trade taxes that keep their utility constant at u_1 and u_2 , respectively. Figure 1a illustrates the case of Nash tariffs imposed by self-interested in the unconstrained one-shot game, i.e. $\lambda_{ij} = 0$ if $i \neq j$. Figure 1b illustrates the case of efficient tariffs where countries maximize the same global welfare function, i.e. $\lambda_{ij} = \lambda_i / \lambda_j > 0$. Figure 1c illustrates the case of self-enforcing tariffs where λ_{ij} is the Lagrange multiplier associated with (7).

game is such that if country j were to deviate from its on-the-equilibrium-path tariffs t_j in a way that affects the welfare of its trading partners $i \neq j$, then others might punish or reward it in the future. If not, they would continue to impose the same on-the-equilibrium-path tariffs t_{-j} .

We view this equilibrium refinement as extremely mild. It excludes equilibria where country j deviates from its on-the-equilibrium-path tariffs t_j without changing the welfare of its trading partners $i \neq j$, but its trading partners nevertheless punish or reward country j for deviating. Such equilibria are implausible for two reasons. First, they require a high level of sophistication among trading partners that are able to sustain greater cooperation by punishing deviations that have no direct welfare effects. Second, they may run afoul of WTO rules. In his discussion of the role of remedies in the WTO system, for instance, Lawrence (2003) notes that under the Understanding on Rules and Procedures Governing the Settlement of Disputes, “allowed responses, particularly retaliation, relate to nullification and impairment of benefits between the parties rather than violations of the rules in general.”

Given this restriction, on-the-equilibrium-path tariffs t_j must solve

$$\begin{aligned} & \max_{t \in \mathcal{T}_j, \{u_i\}} u_j & (7) \\ \text{subject to: } & u_i = \underline{u}_i \text{ for all } i \neq j, \\ & \{u_i\} \in \mathcal{U}(t, t_{-j}), \end{aligned}$$

where \underline{u}_i denotes the utility received by country i along the equilibrium path. The formal argument is straightforward. If t_j does not satisfy (7), then country j could strictly increase its utility without triggering any change in the future behavior of its trading partners, thereby contradicting the optimality of t_j along the equilibrium path.⁹

In such an environment, the welfare weights appearing in (6) correspond to the Lagrange multipliers associated with the utility constraint, $u_i = \underline{u}_i$. Accordingly, the as-if altruistic motives in Definition 2 may capture the primitive determinants of equilibrium utility levels, from differences in geography or size that affect countries' ability to punish and be punished, as in Maggi (1999), to political considerations that affect the extent to which policy makers discount the benefits from future cooperation, as in Conconi et al. (2014). Figure 1c describes what self-enforcing tariffs may look like. Compared to the two cases plotted in Figures 1a and 1b, the indifference curves of the two countries are neither orthogonal nor tangent, but instead intersect at an acute angle. Since countries may disagree on the welfare weights that each of them should receive, a "lens" of Pareto-superior allocations opens up, unlike in Figure 1b. But since countries at least partially internalize the impact of their own actions on others, this lens is smaller than in the one-shot Nash equilibrium depicted in Figure 1a.

2.3 Characterization of Optimal Trade Taxes with As-If Altruism

To characterize optimal trade taxes with as-if altruism, we focus on the set of necessary first-order conditions associated with (6). In any country j , for the vector of trade taxes t_j to be optimal, it must be the case that for any small variation dt around country j 's vector

⁹It should be clear that this formal argument does not rely on countries only choosing tariffs. It also applies if each country j chooses its tariff t_j as well as a vector of other policies $s_j \in \mathcal{S}_j$ to solve

$$\begin{aligned} & \max_{t \in \mathcal{T}_j, s \in \mathcal{S}_j, \{u_i\}} u_j \\ \text{subject to: } & u_i = \underline{u}_i \text{ for all } i \neq j, \\ & \{u_i\} \in \mathcal{U}(t, s, t_{-j}, s_{-j}). \end{aligned}$$

Other policies may include labor and environmental standards, as in Bagwell and Staiger (2001), non-economic policies, as in Limao (2007), or various forms of red tape at the border, as in Maggi et al. (2022).

of trade taxes,

$$du_j + \sum_{i \neq j} \lambda_{ij} du_i = 0. \quad (8)$$

From the budget constraint of the representative consumer in any country i , we know that utility levels in each country are such that $e_i(p_i, u_i) = r_i(p_i) + \tau_i$. Totally differentiating the previous constraint and invoking standard envelope arguments on the demand and supply side, we therefore have

$$e_{i,u} du_i = -m_i \cdot dp^w + t_i \cdot dm_i, \quad (9)$$

where $e_{i,u} \equiv \partial e_i(p_i, u_i) / \partial u_i$ and we have used (3) and (4) to substitute for the change in the lump-sum transfer $d\tau_i$. The first term, $-m_i \cdot dp^w$, captures welfare changes in country i caused by changes in its terms of trade, with $m_i \equiv c_i - y_i$ the vector of country i 's net imports, whereas the second term, $t_i \cdot dm_i$, reflects the fiscal externality associated with changes in tariff revenues.

Substituting (9) into (8), we obtain

$$t_j \cdot dm_j = m_j \cdot dp^w - \sum_{i \neq j} \beta_{ij} d\omega_i, \quad (10)$$

where $\beta_{ij} \equiv \lambda_{ij}(e_{j,u}/e_{i,u})$ is the ratio of the marginal utility of income in country i to the marginal utility of income in country j , evaluated from the point of view of country j , and $d\omega_i \equiv -m_i \cdot dp^w + t_i \cdot dm_i$ denotes the change in country i 's real income caused by changes in its terms of trade and the fiscal externality. Without risk of confusion, we use the convention $\lambda_{jj} = \beta_{jj} = 1$ for all j .

There are many possible ways to rearrange condition (10). One strategy consists of focusing on a series of variations dt that only changes the tax t_{gj} that country j imposes on a single good $g \in \mathcal{G}_j^T$. Another, which we find both theoretically insightful and empirically convenient, consists of considering a variation dt that may affect multiple taxes simultaneously, but instead only affects the net imports m_{gj} of a single good, as in [Costinot and Werning \(2023\)](#) and [Adao et al. \(2023\)](#). This is equivalent to treating all equilibrium variables as implicit functions of country j 's vector of taxable imports $m_j^T \equiv \{m_{gj}\}_{g \in \mathcal{G}_j^T}$ —rather than its trade taxes $t \equiv \{t_{gj}\} \in \mathcal{T}_j$ —and then taking partial derivatives with respect to m_{gj} for all $g \in \mathcal{G}_j^T$.¹⁰

¹⁰Formally, if $\tilde{x}(t)$ denotes the equilibrium value of a variable x as a function country j 's taxes t (holding trade taxes t_{-j} fixed in other countries), then the function of imports $x(m_j)$ that we consider is defined as $x(m_j^T) \equiv \tilde{x}(t^{-1}(m_j^T))$, with $t^{-1}(m_j^T)$ the vector t that solves: $\tilde{m}_{gj}(t) = m_{gj}$ for all $g \in \mathcal{G}_j^T$. This change of

Starting from (10) and implementing this strategy, we obtain the following characterization of optimal trade taxes with as-if altruism.

Proposition 1. *In any country j , the optimal trade tax with as-if altruism satisfies*

$$t_{gj} = \hat{t}_{gj} - \sum_{i \neq j} \beta_{ij} (\partial \omega_i / \partial m_{gj}), \text{ for all goods } g \in \mathcal{G}_j^T, \quad (11)$$

where $\hat{t}_{gj} \equiv m_j \cdot (\partial p^w / \partial m_{gj})$ denotes the opportunistic tariff that would arise if $\beta_{ij} = \lambda_{ij} = 0$ for $i \neq j$.

Proposition 1 highlights two key determinants of country j 's trade taxes. First, country j 's optimal tax on any good g depends on how much restricting imports of that good can help it improve its overall terms of trade, as reflected in $\hat{t}_{gj} \equiv m_j \cdot (\partial p^w / \partial m_{gj})$. This is the classical motive for an optimal tariff. Countries' consumers and firms are price-takers that do not internalize the marginal impact of their import decisions on world prices. The optimal trade tax makes them do so. Second, import restrictions on good g in country j also affect any other country i 's real income, both via changes in its terms of trade and fiscal revenues, as reflected in $\partial \omega_i / \partial m_{gj}$. A country with (as-if) altruistic motives also wants to take these changes into account, with β_{ij} measuring the extent to which it does.

To understand how we will later identify the as-if altruistic motives of a given country j , consider a simpler environment in which there are no trade taxes in the rest of the world, so that $\partial \omega_i / \partial m_{gj} = -m_i \cdot (\partial p^w / \partial m_{gj})$. If $\beta_{ij} = 0$ for all $i \neq j$, we should therefore observe the opportunistic tariff $t_{gj} = \hat{t}_{gj}$. If $\beta_{ij} = 1$ for all $i \neq j$ instead, then $t_{gj} = 0$ since $m_j \cdot (\partial p^w / \partial m_{gj}) + \sum_{i \neq j} m_i \cdot (\partial p^w / \partial m_{gj}) = 0$ by the good market clearing condition, $\sum_{i \in \mathcal{I}} m_i = 0$. Intuitively, changes in world prices are pure transfers between exporting and importing countries; so, the terms-of-trade manipulation motive disappears when country j puts the same marginal utility of income on all countries, and free trade should be observed. The same simple manipulation of the good market clearing condition implies that if $\beta_{ij} = \beta \in (0, 1)$ for all $i \neq j$, then $t_{gj} = (1 - \beta)\hat{t}_{gj}$, i.e. a smaller tariff t_{gj} than the one predicted by opportunistic terms-of-trade manipulation. The general idea, which we will put to work in order to estimate the full matrix of welfare weights $\{\beta_{ij}\}$, is that one can use differences between t_{gj} and \hat{t}_{gj} in order to reveal the extent to which country j 's internalizes the impact of its own policies.

Among the previous examples, the case $\beta_{ij} = 1$ for all $i \neq j$ is an important focal point that nicely illustrates how the introduction of formal rules may create as-if altruistic mo-

variables requires that, local to the observed equilibrium, the inverse $t^{-1}(m_j^T)$ exists and is unique, a weak requirement that will be satisfied in our subsequent analysis.

tives among otherwise self-interested countries. Suppose, following [Bagwell and Staiger \(1999\)](#), that a given country j may only consider (global) tariff changes that are reciprocal in the sense that when evaluated at the original prices p^w , the changes in country j 's net imports must satisfy $p^w \cdot dm_j = 0$. Since country j 's trade must be balanced, both before and after tariff changes, price and import changes must also satisfy $d(p^w \cdot m_j) = 0$. The two previous observations immediately imply $m_j \cdot dp^w = 0$. From equation (10), it follows that a self-interested country j , with $\beta_{ij} = 0$ for all $i \neq j$, would choose its optimal tariff under the previous rule so that $t_j \cdot dm_j = 0$. A solution to this equation, of course, is $t_j = 0$. That is, a self-interested country required to choose among reciprocal tariff changes, in the sense of [Bagwell and Staiger \(1999\)](#), would act, at least locally, as if it had altruistic motives such that $\beta_{ij} = 1$ for all $i \neq j$.¹¹

2.4 Extensions

We have characterized optimal trade taxes with as-if altruism in a neoclassical economy that features specific trade taxes as the only policy instruments, no motive for domestic redistribution, and no source of distortions beside trade taxes. We briefly discuss here how departures from these benchmark assumptions would or would not affect Proposition 1. A more detailed discussion of these issues can be found in [Adao et al. \(2023\)](#).

Other Policy Instruments. For expositional purposes, we have focused so far on an environment where countries choose specific rather than ad-valorem trade taxes. The extension to an environment with ad-valorem trade taxes is straightforward. If countries can choose ad-valorem trade taxes $\{t_{gj}^{\text{av}}\}$ such that $p_{gj} = p_g^w(1 + t_{gj}^{\text{av}})$, then the optimal ad-valorem trade tax is equal to $t_{gj}^{\text{av}} = t_{gj}/p_g^w$, with t_{gi} satisfying equation (11). The only subtle observation is that the value of the partial derivatives entering this expression (e.g. $\partial\omega_i/\partial m_{gj}$) may differ depending on whether one assumes that other countries $i \neq j$ are holding fixed their specific or ad-valorem tariffs. Given their prevalence in practice, we will assume that ad-valorem tariffs are being held fixed in all subsequent sections.

Because trade taxes are the only taxes available to governments in Section 2.1, the only fiscal externalities entering Proposition 1 are those associated with the revenues from

¹¹Faithful readers of [Bagwell and Staiger \(1999\)](#) may rightly remember that their results do not require countries' choices to be free trade. The only reason why $t_j = 0$ appears in the above argument is because, so far, we have abstracted from either domestic redistribution or distortions. When one introduces such considerations, as [Bagwell and Staiger \(1999\)](#) do and as we will in the next subsection, the exact same argument goes through, but with optimal tariffs that are potentially non-zero. The only difference is that the first-order condition in equation (10) now also includes these other motives for trade protection, hence the non-zero tariff choices.

trade taxes. If there are other policy instruments available, but these do not create fiscal externalities, then equation (11) is unchanged. Such instruments therefore would only affect our estimates of the weights β_{ij} to the extent they affect the value of the statistics in (11). For instance, if there are unrestricted lump-sum transfers between countries, then all trade taxes should be equal to zero, leading to $\beta_{ij} = 1$ for all $i \neq j$.

If other taxes also create fiscal externalities, then those should ideally be added to equation (11). For concreteness, suppose that governments may also tax output, with $t_j^y \equiv \{t_{gj}^y\}$ the (specific) producer taxes in country i . In this more general environment, Proposition 1 generalizes to

$$t_{gj} = (t_{gj})_{\text{Proposition 1}} - \sum_{i \in \mathcal{I}} \sum_{g' \in \mathcal{G}} \beta_{ij} [t_i^y \cdot (\partial y_{g'i} / \partial m_{gj})],$$

where $\partial y_{g'i} / \partial m_{gj}$ denotes the change in output of good g' in country i caused by a change in imports of good g by country j .

Domestic Redistribution. By assuming a representative agent in each country, Proposition 1 abstracts from domestic redistribution. More generally, suppose that each country i is populated by multiple individuals indexed by $n \in \mathcal{N}_i$, each potentially with different preferences, different endowments, and different welfare weights in the social welfare function of their own government. Under the assumption that altruistic motives across countries do not affect the premia assigned to the income of different individuals from the same country, i.e. that each country j assigns a welfare weight $\beta_{ij}(n) = \beta_{ij} + \beta_i(n)$ on any individual $n \in \mathcal{N}_i$, Proposition 1 then generalizes to

$$t_{gj} = (t_{gj})_{\text{Proposition 1}} - \sum_{i \in \mathcal{I}} \sum_{n \in \mathcal{N}_i} \beta_i(n) \times [\partial(\omega_i(n) - \bar{\omega}_i) / \partial m_{gj}], \quad (12)$$

where $\partial \omega_i(n) / \partial m_{gj}$ denotes the change in individual n 's real income caused by the increase in net imports of good g from country j via its impact on the local prices p_i in country i and $\partial \bar{\omega}_i / \partial m_{gj} \equiv \frac{1}{|\mathcal{N}_i|} \sum_{n \in \mathcal{N}_i} \partial \omega_i(n) / \partial m_{gj}$ denotes the average impact. In the special case where $\beta_{ij} = 1$ for all $i \neq j$, the tariff in equation (12) coincides with the tariffs chosen under "trade talks" in Grossman and Helpman (1995) and the "politically optimal tariffs" in Bagwell and Staiger (1999).

Equation (12) clarifies that identification of β_{ij} in our baseline analysis therefore implicitly relies on within- and between-country redistributive motives being orthogonal to each other. Such a condition would fail, for instance, if import restrictions of agricultural goods help country i 's domestic redistributive objectives by raising the real

wages of its farmers, yet systematically hurt the terms of trade of trading partners with a comparative advantage in farming activities. To address this issue, we will consider in our sensitivity analysis alternative environments that allow for heterogeneous individuals within each country and explicitly control for the within-country considerations described in equation (12).

Distortions. One way to introduce distortions in the previous environment is to allow production and consumption to be subject to externalities $z \equiv \{z_k\}$. Formally, suppose that production sets and utility functions now take the form $Y_i(z)$ and $u_j(c, z)$, respectively, with the externalities a function of the choices of firms and consumers around the world, $z \in \mathcal{Z}(\{y_i, c_i\})$. Since Proposition 1 reflects a necessary first-order condition, the introduction of a new second-best motive for trade protection would enter equation (11) additively.¹² This leads to

$$t_{gj} = (t_{gj})_{\text{Proposition 1}} + \epsilon_{gj}, \quad (13)$$

where $\epsilon_{gj} \equiv \sum_{i \in \mathcal{I}} \beta_{ij} (e_{i,z} - r_{i,z}) \cdot (\partial z / \partial m_{gj})$ denotes the social marginal costs associated with externalities caused by imports of good g by country j , with $e_{i,z} \equiv \{\partial e_i(p_i, z, u_i) / \partial z_k\}$ and $r_{i,z} \equiv \{\partial r_i(p_i, z) / \partial z_k\}$ the derivatives of the expenditure and revenue functions with respect to different externalities. This provides one structural interpretation of the error term in our baseline regression. We come back to this point in Section 4.1.

3 Measuring the Incidence of Import Restrictions

Our goal is to use Proposition 1 to reveal each country's valuation of its trading partners' welfare from the trade taxes that it chooses to impose and, in turn, to explore the efficiency and distributional properties of the global trading system. Doing so requires measures of the incidence of import restrictions entering equation (11), namely the opportunistic tariff $\hat{t}_{gj} \equiv m_j \cdot (\partial p^w / \partial m_{gj})$ and the changes in foreign real income $\partial \omega_i / \partial m_{gj}$. To arrive at such measures, we build and calibrate a quantitative model of the world economy that imposes further parametric restrictions on Section 2's general environment.

¹²The same observation applies to other distortions such as those due to imperfect competition, as discussed in Adao et al. (2023). It applies, in particular, to firm-delocation effects, as in Venables (1987) and Ossa (2011), or profit-shifting effects, as in Brander and Spencer (1984) and Mrazova (2023).

3.1 A Quantitative Model of the World Economy

Our quantitative model of the world economy builds on [Fajgelbaum et al. \(2020\)](#). Production and utility functions are nested CES, with the nesting structure chosen to allow for a flexible pattern of substitution across goods subject to the availability of production and trade data.

Supply. In each origin country i , the representative firm can allocate a fixed endowment of labor, N_i , to the production of multiple products $h \in \mathcal{H}_s$ in different sectors $s \in \mathcal{S}$ and for multiple destinations $j \in \mathcal{I}$. The labor resource constraint is

$$\sum_{j \in \mathcal{I}} \sum_{s \in \mathcal{S}} \sum_{h \in \mathcal{H}_s} \ell_{ijh} \leq N_i, \quad (14)$$

where ℓ_{ijh} denotes the amount of labor from country i used in to produce product h for country j . For a given product $h \in \mathcal{H}_s$ and destination country j , the gross output of country i 's representative firm is equal to

$$q_{ijh} = \theta_{ijh} \left[(\ell_{ijh})^{\alpha_{is}} \prod_{k \in \mathcal{S}} (Q_{ik,j,h})^{\alpha_{iks}} \right], \quad (15)$$

$$Q_{ik,j,h} = \left[\sum_{c=H,F} (\theta_{ik}^c)^{\frac{1}{\kappa}} (Q_{ik,j,h}^c)^{\frac{\kappa-1}{\kappa}} \right]^{\frac{\kappa}{\kappa-1}}, \quad (16)$$

$$Q_{ik,j,h}^c = \left[\sum_{v \in \mathcal{H}_k} (\theta_{ikv}^c)^{\frac{1}{\eta}} (Q_{ikv,j,h}^c)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (17)$$

$$Q_{ikv,j,h}^c = \left[\sum_{o \in \mathcal{I}_i^c} (\theta_{oikv}^c)^{\frac{1}{\sigma}} (q_{oiv,j,h})^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \quad (18)$$

where $q_{oiv,j,h}$ denotes intermediate inputs of product v from country o delivered to country i used in the production of good (i, j, h) , and \mathcal{I}_i^c denotes either the set of foreign countries that country i imports from, with $\mathcal{I}_i^c \equiv \{j\}_{j \neq i}$ if $c = F$, or country i itself in the case of domestic inputs, with $\mathcal{I}_i^c \equiv \{i\}$ if $c = H$. In this formulation, $\kappa \geq 0$ is the elasticity of substitution between domestic consumption and imports, within any given sector; $\eta \geq 0$ is the elasticity of substitution between products, within any of these two nests; and $\sigma \geq 0$ is the elasticity of substitution between different foreign origins, within any given product. We normalize input demand shifters so that $\alpha_{is} + \sum_{k \in \mathcal{S}} \alpha_{iks} = \sum_{c=H,F} \theta_{ik}^c = \sum_{v \in \mathcal{H}_k} \theta_{ikv}^c = \sum_{o \in \mathcal{I}_i^c} \theta_{oikv}^c = 1$. Note that trade costs of the standard iceberg form are implicitly embed-

ded in input demand shifters. If a product v from sector k is non-tradable from an origin o to country i , then $\theta_{oikv}^c = 0$.

Demand. In each destination country j , the utility of the representative consumer is

$$u_j = \prod_{k \in \mathcal{S}} (C_{jk})^{\gamma_{jk}}, \quad (19)$$

$$C_{jk} = \left[\sum_{c=H,F} (\theta_{jk}^c)^{\frac{1}{\kappa}} (C_{jk}^c)^{\frac{\kappa-1}{\kappa}} \right]^{\frac{\kappa}{\kappa-1}}, \quad (20)$$

$$C_{jk}^c = \left[\sum_{h \in \mathcal{H}_k} (\theta_{jkh}^c)^{\frac{1}{\eta}} (C_{jkh}^c)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (21)$$

$$C_{jkh}^c = \left[\sum_{i \in \mathcal{I}_j^c} (\theta_{ijkh}^c)^{\frac{1}{\sigma}} (c_{ijh})^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \quad (22)$$

where $c_j \equiv \{c_{ijh}\}$ denotes the consumption of all products h from all origin countries i that have been delivered to country j . Except for the Cobb-Douglas parameters $\{\gamma_{jk}\}$ that may differ from $\{\alpha_{iks}\}$ in equation (15), note that all other demand shifters as well as elasticities in equations (20)-(22) are the same as in equations (16)-(18). That is, within any country, firms and the representative consumer demand the same “sector composite,” a standard data-driven restriction in quantitative trade models. In line with our treatment of technology, we impose the normalization $\sum_{k \in \mathcal{S}} \gamma_{jk} = 1$.

Government. In each country j , we assume that there are no export taxes or subsidies. The only available trade taxes are ad-valorem import tariffs t_{ijh}^{av} that may vary across foreign origins $i \neq j$ and products h . We assume that the transfer T_j received by country j is fixed as a share of world GDP.

Mapping between quantitative and general models. The quantitative model presented here is a special case of the general model in Section 2. A good g corresponds to a unique origin-destination-product triplet (i, j, h) . Each origin country i has a production set Y_i , which is determined by the resource constraint (14) and the production functions (15)-(18). Each destination country j obtains utility u_j from consuming goods delivered there, as described in (19)-(22). The specific tariff t_{gj} equivalent to the ad valorem tariff t_{gj}^{av} imposed on good g by country j 's government satisfies $t_{gj} = t_{gj}^{\text{av}} p_g^w$, with p_g^w the world price of good g . Note also that since a good corresponds to a unique triplet $g = (i, j, h)$,

two distinct countries cannot produce the same good. Thus for each good imported by country j , the vector of net imports m_j is also the vector of gross imports.

3.2 Baseline Calibration

The last piece of information needed to measure the incidence of import restrictions in equation (11) consists of the values of the structural parameters that determine the competitive equilibrium of our quantitative model. These parameters comprise the three elasticities, $\{\kappa, \eta, \sigma\}$, as well as the various technology and preference shifters in (15)-(18) and (19)-(22), the labor endowments $\{N_i\}$, the international transfers $\{T_j\}$, and the specific import tariffs, $\{t_{gj}\}$. We now briefly describe how we calibrate them. Details about data construction and calibration can be found in Appendix A.1 and Appendix C.2, respectively.

Elasticities. We set the values of κ , η , and σ equal to Fajgelbaum et al.’s (2020) estimates.¹³ Specifically, we set the elasticity of substitution across domestic and foreign inputs to $\kappa = 1.19$, the elasticity of substitution across imports from different products within sectors to $\eta = 1.53$, and the elasticity of substitution across origins of the same product to $\sigma = 2.53$.

Other Structural Parameters. We set the values of the technology shifters, preference shifters, labor endowments, and international transfers to match global data from 2001 on output and input use by country and sector—from the OECD Inter-Country Input-Output (ICIO) database—and bilateral international trade flows by country pair and product—from the CEPII BACI database. The set of countries \mathcal{I} features 28 distinct trading partners: the EU and the 26 largest non-EU countries in ICIO (accounting for 91% of global trade in 2001) as well as an additional rest-of-the-world aggregate that combines all other countries, see Table A.1. The set of sectors \mathcal{S} consists of 44 industries based on the ICIO classification (which is similar to ISIC revision 4 categories); these are listed in Table A.2. The set of all products $\mathcal{H} \equiv \cup_{s \in \mathcal{S}} H_s$ is based on the 6-digit HS system (revision 1, from 1996), resulting in 5,113 products for which BACI reports positive trade in 2001, plus a set of sector-specific fictitious products that accommodate domestic trade flows in all sectors and international trade flows in non-merchandise sectors. Without loss of

¹³Despite the fact that our quantitative model is more general than their original model—since it models import foreign import demand and export supply via the general equilibrium supply and demand equations above rather than via partial equilibrium functions—Fajgelbaum et al.’s (2020) estimating equations for κ , η , and σ remain consistent with the parametric assumptions imposed in Section 3.1.

generality, we choose units of account so that the local price p_{gj} of any good g sold in a destination j is equal to one in our baseline calibration.

Import Tariffs. We use data on import tariffs from the UNCTAD TRAINS (obtained via the WITS interface) database, which reports ad-valorem equivalent tariffs at the 6-digit HS level from 1988 onwards. This source collates available information on the MFN and preferential trade agreement (PTA) tariffs that reporting destination countries j charge on origin countries i on each product h .¹⁴ We further augment this tariff information with the discriminatory tariffs that a subset of countries charges on non-WTO members, as reported by USITC and MAcMap. When tariff information is missing for a given importer in 2001, we apply the interpolation procedure (using available tariff information from proximate years) in Teti (2023) and Caliendo et al. (2023) in order to arrive at a complete set of data on ad-valorem equivalent (AVE) tariffs for all origin-destination-product triplets $g = (i, j, h)$, and hence the AVE tariff charged by importer j on any good g , t_{gj}^{av} . We then compute the tariffs charged by the rest-of-the-world aggregate via the simple average of the countries in that group. Under our price normalization, the associated specific import tariff is therefore equal to $t_{gj} = t_{gj}^{\text{av}} / (1 + t_{gj}^{\text{av}})$.

3.3 Model-Implied Incidence of Import Restrictions

In our empirical analysis, we will use equation (11) to estimate each importer j 's vector of welfare weights $\{\beta_{ij}\}$ via a linear regression whose dependent variable is the difference between observed tariffs t_{gj} and opportunistic tariffs $\hat{t}_{gj} \equiv m_j \cdot (\partial p^w / \partial m_{gj})$ and whose regressors are the changes in real income $\{\partial \omega_i / \partial m_{gj}\}$ of various exporters i when country j restricts its imports of good g . Before presenting our estimates of welfare weights, we describe key features of the previous variables. The full procedure used to compute \hat{t}_{gj} and $\partial \omega_i / \partial m_{gj}$ can be found in Appendix C.4.

Opportunistic Tariffs vs. Observed Tariffs. Converting the opportunistic specific tariffs \hat{t}_{gj} that arise in our empirical model into their ad-valorem equivalents—by simply dividing \hat{t}_{gj} by the world price p_{gj}^w , which is equal to $1 / (1 + t_{gj}^{\text{av}})$ under our calibration—leads to a median value of 55%.¹⁵ This falls well within the range of optimal tariffs suggested by the work of Broda et al. (2008), Ossa (2014), and Fajgelbaum et al. (2020). Absent

¹⁴The set of PTAs in TRAINS includes all PTAs for which importers have supplied product-level tariff information to TRAINS/WITS. This includes non-traditional PTAs such as the Generalized System of Preferences scheme.

¹⁵The full distribution of \hat{t}_{gj} is reported in Appendix Figure B.1.

global input-output linkages, Fajgelbaum et al.’s (2020) original model implies optimal tariffs around 25%.¹⁶ Ossa (2014) reports a median value of optimal tariffs around 60% across 7 regions and 33 sectors, remarkably similar to ours despite different modeling assumptions and empirical strategies. At the higher end of the spectrum, Broda et al. (2008) finds a median value of the optimal tariff of 160% among non-WTO countries.

Observed tariffs t_{gj} tend to be much lower than opportunistic tariffs. As shown in Appendix Figure B.2, the distribution of the dependent variable in our regressions $t_{gj} - \hat{t}_{gj}$ is almost always negative. Through the lens of Proposition 1, this already suggests that countries internalize the impact of their policy on others to a significant extent—though it says nothing at this point about the identity of countries who give or receive more weight from others. Our estimation below draws on the substantial heterogeneity in $t_{gj} - \hat{t}_{gj}$, across importers and goods, to reveal the shape of such altruistic motives.¹⁷

Sensitivity of Foreign Real Income to Changes in Imports. We turn now to the regressors—the sensitivity of the real earnings of exporters to changes in the imports of their trading partners, i.e. $\partial\omega_i/\partial m_{gj}$ —that our empirical procedure projects $t_{gj} - \hat{t}_{gj}$ onto. Appendix Figure B.4 displays, in a 28×28 matrix, the mean value of $\partial\omega_i/\partial m_{gj}$, across all goods $g = (i, j, h)$ that are sold in our sample by an exporter i to importer j . A few features are worth pointing out. First, entries are positive for all cells. Thus, when a typical country imports more from a typical exporter, this improves the exporter’s real income. This happens in our calibrated model mainly because the terms of trade of the exporter improve. Fiscal externalities triggered by changes in another country’s imports, which are also part of changes in foreign real income, are an order of magnitude smaller. Second, large row entries tend to correspond to countries that have large exports to a small number of importers. Finally, large column entries tend to correspond to countries that are large importers of many products and so exert larger impacts on world prices, consistent with our earlier discussion of optimal tariffs.

In addition to the mean value of $\partial\omega_i/\partial m_{gj}$ within each exporter-importer pair (i, j) discussed here, there remains substantial variation in terms of how import restrictions on different goods may affect real income in the origin countries, as illustrated in Appendix Figure B.5. We will use this source of variation to identify as-if altruism from observed

¹⁶Despite their estimates of perfectly elastic foreign export supply curves within each sector, optimal tariffs are non-zero because of general-equilibrium considerations.

¹⁷Although the parametric model of Section 3.1 features nested CES technology and preferences that only rely on a small number of constant elasticities, the heterogeneity in the trade flows and input-output flows targeted in our calibration generates variation in countries’ ability to manipulate their terms of trade. In our model, larger importers have greater monopsony power, leading to larger opportunistic tariffs as can be seen from Appendix Figure B.3.

trade taxes in the next section.

4 A World Trading System for Whom?

4.1 Empirical Specification

Using Proposition 1, we propose to estimate the welfare weight that an importer j assigns to each of its trading partners i by regressing the difference between importer j 's observed and opportunistic tariffs on measures of the sensitivity of its trading partners' real income to j 's imports. Moving opportunistic tariffs \hat{t}_{gj} from the right- to the left-hand side of (11) and adding an error term, we get

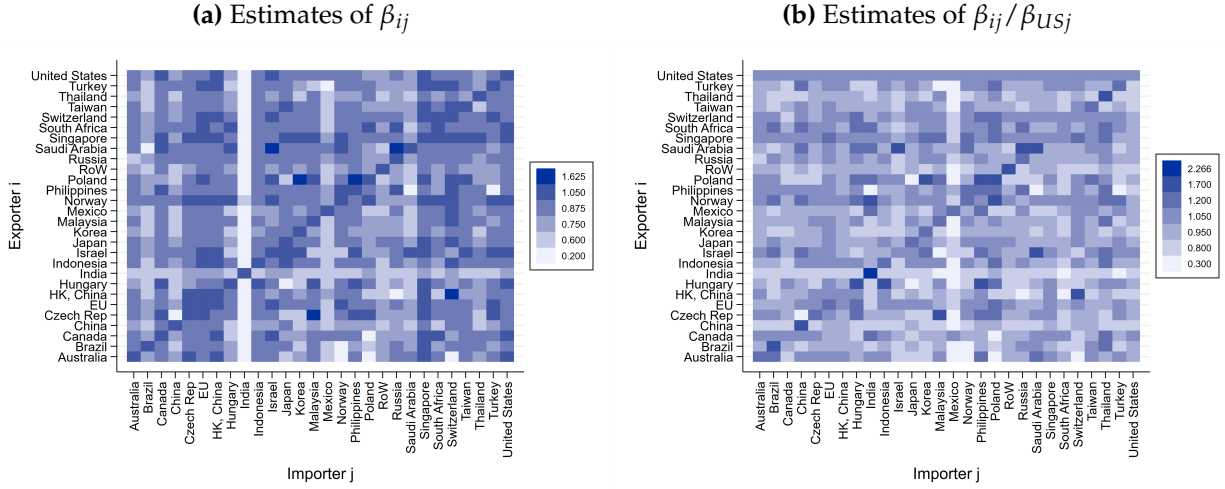
$$t_{gj} - \hat{t}_{gj} = - \sum_{i \neq j} \beta_{ij} (\partial \omega_i / \partial m_{gj}) + \epsilon_{gj}. \quad (23)$$

This is a linear regression model with 756 parameters $\{\beta_{ij}\}$, one corresponding to each pair of our 28 destinations j and 27 origins $i \neq j$. Each observation “ gj ” corresponds to an origin-destination-product triplet. Our sample includes, for each destination country j , the largest origin-products that account for 95% of that destination's imports by value in 2001. Across all importers, this yields a total of 217,454 observations. The error term ϵ_{gj} in (23) can either be interpreted as measurement error in tariffs, mistakes by the government in their tariff choices, or as additional corrective motives for trade policy in the presence of distortions, as discussed in Section 2.4.¹⁸ The case where ϵ_{gj} may also capture domestic redistribution will be discussed in detail in Section 4.4.

OLS estimation of the welfare weights $\{\beta_{ij}\}$ in equation (23) would require the regressors $\{\partial \omega_i / \partial m_{gj}\}$ to be uncorrelated with the residual ϵ_{gj} . One reason to doubt such orthogonality arises from simultaneity bias: tariffs (the dependent variable) may have their own causal impact on the sensitivity of the real earnings of exporters to changes in the imports of their trading partners. This concern is particularly acute given the relationship discussed in Section 3.3 between changes in real earnings and equilibrium outcomes—especially bilateral trade flows—which are themselves a function of tariffs. We therefore use an instrumental variable (IV) specification in which the IVs again leverage the incidence of import restrictions, but now computed around a counterfactual economy with zero tariffs, i.e., $(\partial \omega_i / \partial m_{gj})_{t=0}$. This formalizes the idea in [Trefler \(1993\)](#) and [Goldberg](#)

¹⁸Provided that externalities z only enter utility multiplicatively, i.e. $u_j(c, z) = E_j(z)u_j(c)$, the predictions of our quantitative model would remain unchanged, with the opportunistic tariffs \hat{t}_{gj} and the sensitivity of foreign income $\partial \omega_i / \partial m_{gj}$ as described in Section 3.3.

Figure 2: Baseline Estimates of Welfare Weights



Notes: This figure displays estimates of welfare weights that importer j places on exporter i obtained from the IV estimation of (23). We use the convention $\beta_{jj} = 1$. Figure 2a reports the original estimates (i.e. $\hat{\beta}_{ij}$) and Figure 2b reports each estimate normalized by the importer’s weight on the US (i.e. $\hat{\beta}_{ij} / \hat{\beta}_{USj}$).

and Maggi (1999) that one should predict the impact of imports on real income using primitive economic forces that are assumed to be independent from tariffs.

Finally, when estimating equation (23), we cluster standard errors by origin-sector pair. This allows for arbitrary correlation in residuals across importers for goods originating from the same exporter and sector.

4.2 Baseline Estimates of Welfare Weights

The heatmap in Figure 2a presents the 756 values of $\hat{\beta}_{ij}$ that we obtain from equation (23) using the IV estimator described above, along with the convention of $\hat{\beta}_{ii} = 1$ to populate the diagonal. Two features about the off-diagonal elements are immediately apparent. First, many are substantially greater than zero: for example, the 10th percentile is 0.62. And this is true even when adjusting for sampling variance, since 747 out of the 756 estimates $\hat{\beta}_{ij}$ are statistically significantly greater than zero at a 5% significance level. This finding is strikingly inconsistent with the one-shot Nash tariffs described in Figure 1a— in which $\beta_{ij} = 0$ for all $i \neq j$, and hence the matrix of values corresponds to the identity matrix.

Second, while all off-diagonal estimates $\hat{\beta}_{ij}$ are positive, very few of the estimates rise to the level of one that would be consistent with the efficient tariffs described in Figure 1b. For example, the average is 0.81 and the 90th percentile value is 0.97. This reflects an

implicit national bias in their preferences: for a typical importer, the value of one dollar transferred to another country is 19% lower than the value of that same dollar transferred to its own residents. Again, a version of this finding that adjusts for uncertainty—a formal joint test of the hypothesis that $\beta_{ij} = 1$ for all $i \neq j$ —rejects at standard levels.

The existence of national bias uncovered in most countries already points towards the world trading system’s inability to deliver an equilibrium on the global efficiency frontier. We investigate this hypothesis further in Figure 2b. It again reports our estimates of the value that each importer j implicitly places on transfers to an exporter i , but now relative to a common reference exporter, which we take to be the United States, i.e. $\hat{\beta}_{ij}/\hat{\beta}_{USj}$. If the world economy were on the global efficient frontier, then there would be a common vector of social marginal utility of income $\{\beta_i\}$ such that the true values of β_{ij} would satisfy $\beta_{ij}/\beta_{USj} = \beta_i$ for all importers j and exporters i . Put differently, the matrix displayed in Figure 2b would be rank one, with no variation across columns, whereas it is hard to discern any column structure to the displayed estimates at all. While sampling variance could explain this, it is straightforward to conduct the formal test of $\beta_{ij}/\beta_{USj} = \beta_i$, separately for each exporter i . The results from such tests are reported in Appendix Table B.1 and the null of efficiency is rejected ($p < 0.01$) in every case. Perhaps surprisingly, we can also reject for all exporters that $\beta_{ij}/\beta_{USj} = \beta_i$ for all $j \neq i$, indicating that the departure from global efficiency is not only driven by national bias but also by dispersion in relative values among foreign trading partners.¹⁹ This implies that the world trading system could enjoy Pareto improvements by arbitraging differences in the returns to (trade-policy-induced) transfers that are currently being made across its members.

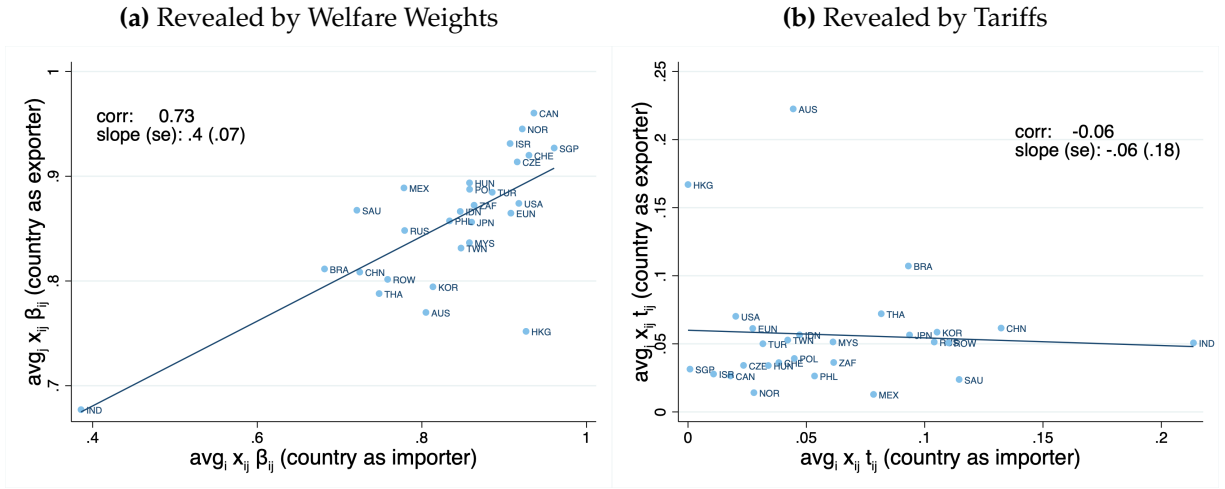
4.3 Reciprocity in the World Trading System

It is often argued that reciprocity—in which actors exchange a good for a good and a bad for a bad—is key to sustaining cooperation in a variety of contexts (Axelrod, 1984) and in international relations in particular (Keohane, 1986). We now propose to use our estimates of welfare weights to look for traces of such cooperative behavior.

A First Look. The case of India in Figure 2a already gives a hint of the importance of such considerations. As one can see from the “Indian column,” India puts low values on

¹⁹This is true even if we focus on the subset of importer regions that were WTO members in 2001. Further visualization of our Pareto-efficiency test can be found in Appendix Figure B.6. There we plot two histograms of $\hat{\beta}_{ij}/\hat{\beta}_{USj}$ values, one after residualizing them with respect to a constant and one that is further residualized with respect to exporter fixed-effects. Global efficiency mandates that the latter distribution should display no variance, whereas in practice it shows just as much variance as the former distribution.

Figure 3: Reciprocity in the World Trading System



Notes: This figure assesses the extent of reciprocity in the world trading system in 2001. In Figure 3a, for each country j , we plot on the x-axis the average value of $\hat{\beta}_{ij}$ for all $i \neq j$, weighted by its imports in the counterfactual free trade equilibrium, against the average value of $\hat{\beta}_{ji}$ for all $i \neq j$, weighted by exports in the counterfactual free trade equilibrium on the y-axis. In Figure 3b, for each country j , the x-axis is the average import tariff that j imposes on other countries and the y-axis is the average tariff that other countries impose on j , weighted by imports and exports in the counterfactual free trade equilibrium, respectively.

other countries' welfare, and as one can see from the "Indian row," other countries appear to reciprocate by putting low values on Indian welfare. More systematically, Figure 3a plots on the x-axis the average of the welfare weights $\hat{\beta}_{ij}$ that each importer j gives to others (weighted by its import values) against the average of the welfare weights that the same country j receives from others (weighted by its export values) on the y-axis.²⁰ The strong upward-sloping relationship (both with and without the outlier, India, included) is clear evidence of reciprocity at work.

At this point, a skeptical reader may wonder whether the pattern of reciprocity that we have uncovered could be observed more easily by looking directly at the raw tariff data. Figure 3b shows that the answer is no. On the x-axis is the average tariff charged by each country j and on the y-axis is the average tariff imposed on the same country by others, again weighted by import and export values, respectively. We see that raw tariffs paint a much murkier picture. There is no clear relationship between the average tariffs as exporters and importers, with a correlation between the two of -0.06 . In comparison, the correlation amongst corresponding estimates of welfare weights in Figure 3a is 0.73.

²⁰To construct the weights we use the value of exports in the counterfactual free trade equilibrium used in our IV. Using the observed value of exports instead makes little difference.

Which Countries Give and Receive Higher Welfare Weights? As stressed by [Bagwell and Staiger \(1999\)](#), “the norm under which one country agrees to reduce its level of protection in return for a reciprocal “concession” from its trading partner” is one of the pillars of the GATT and the WTO. It is therefore also natural to ask whether the pattern of reciprocity in welfare weights displayed in [Figure 3](#) might be an obvious and somewhat mechanical manifestation of formal GATT/WTO rules. The answer again is no, both for theoretical and empirical reasons.

From a theoretical standpoint, [Bagwell and Staiger \(1999\)](#) have offered a first and influential formalization of the reciprocity principle inside the GATT/WTO. Their results, however, simply do *not* imply that the matrix of $\{\hat{\beta}_{ij}\}$ displayed in [Figure 3](#) should be symmetric. As discussed in [Section 2.3](#), their results offer conditions under which $\hat{\beta}_{ij} = 1$ may be observed (though not necessarily for all countries j).

From an empirical standpoint, the fact that reciprocity is more apparent in welfare weights (in [Figure 3a](#)) than tariffs (in [Figure 3b](#)) already suggests that it reflects a broader set of forces than the basic mechanics of negotiated tariff concessions. To investigate this issue more systematically, as well as to offer further insights about the nature of international cooperation, we now consider descriptive regressions of the welfare weight $\hat{\beta}_{ij}$ —that country j places on country i —on the welfare weight $\hat{\beta}_{ji}$ —that country j places on country i —and a series of controls—that range from participation in formal trade agreements to standard “gravity” covariates like physical distance, population, and GDP per capita. The results are reported in [Table 1](#).

We begin in column (1) with a specification that extends the study of reciprocity introduced above. Here, conditional on a constant, we regress $\hat{\beta}_{ij}$ on the value of $\hat{\beta}_{ji}$ to assess the extent to which i internalizing the impact of its policy on j is reciprocated by j internalizing the impact of its policy on i . In line with [Figure 3a](#), countries tend to place higher value on other countries that also value them more. The causal interpretation of the estimated coefficient would be that, for a typical importer, moving from no altruism ($\beta_{ij} = 0$) to no national bias ($\beta_{ij} = 1$) triggers an increase of 0.34 in the partner’s reciprocal weight.

In the next two columns, we ask whether the previous pattern can be accounted for by participation in formal trade agreements. In column (2), we include a set of dummies that equal one or zero for all combinations of whether the exporter i and importer j are WTO members or not (apart from the omitted category, in which both are WTO members). In column (3), we further add a dummy for whether there is a Preferential Trade Agreement (PTA) between the exporter and importer. As might have been expected, we see that when two countries are part of the same PTA the importing country tends to assign the exporter a higher welfare weight (of approximately 0.06). In contrast, perhaps more

Table 1: Which Countries Give and Receive Higher Welfare Weights?

	Dependent variable: $\hat{\beta}_{ij}$			
	(1)	(2)	(3)	(4)
$\hat{\beta}_{ji}$	0.342*** (0.040)	0.346*** (0.041)	0.333*** (0.041)	0.192*** (0.038)
$D\{i \in \text{WTO}, j \notin \text{WTO}\}$		-0.044** (0.018)	-0.035* (0.019)	-0.037** (0.018)
$D\{i \notin \text{WTO}, j \notin \text{WTO}\}$		0.085 (0.107)	0.100 (0.102)	0.064 (0.103)
$D\{i \notin \text{WTO}, j \in \text{WTO}\}$		0.038 (0.023)	0.046** (0.023)	0.037* (0.020)
$D\{ij \text{ have PTA}\}$			0.063*** (0.011)	0.046*** (0.013)
log distance _{ij}				-0.017*** (0.002)
log population _i				-0.003 (0.006)
log population _j				-0.031*** (0.005)
log p.c. income _i				0.017*** (0.006)
log p.c. income _j				0.030*** (0.007)
Constant	0.539*** (0.034)	0.535*** (0.035)	0.526*** (0.034)	0.792*** (0.039)
Observations	784	784	784	784
R^2	0.117	0.131	0.160	0.293

Notes: This table reports estimates of a regression of $\hat{\beta}_{ij}$ obtained from (23) on the regressors listed on each row, plus a constant.

surprisingly, the role of the WTO is mixed: there is statistically significant evidence of non-WTO members assigning lower weights towards WTO members (by about 0.04), but the evidence for WTO member treating non-WTO members differently is much weaker. Beyond these agreement effects *per se*, we see that the estimated coefficients on $\hat{\beta}_{ji}$ are almost unchanged in columns (1) through (3), implying that reciprocity is not a form of behavior that is created within formal trade agreements.

Column (4) shows that the positive relationship between $\hat{\beta}_{ij}$ and $\hat{\beta}_{ji}$ is also robust to controlling for physical distance, population, and GDP per capita.²¹ Everything else being equal, countries place lower weights on partners that are further away. So do larger and poorer countries. But these considerations have little effect on the relationship between $\hat{\beta}_{ij}$ and $\hat{\beta}_{ji}$, with the estimated coefficient in column (4) equal to 0.19.²²

As a final exercise, we also examine the estimated relationship between $\hat{\beta}_{ij}$ and $\hat{\beta}_{ji}$ separately for each importer in our sample. The results are reported in Appendix Figure B.7, with importers ordered by the numbers of years that they have been a member of the GATT/WTO. Despite only having 27 observations for each importer, the estimated coefficient is positive and statistically significant at the 5% level for 20 out of the 28 importers in our sample. There is no apparent relationship between the magnitude of the estimated coefficient and the GATT/WTO tenure of the importer, suggesting that reciprocal behavior is widespread, and it is not stronger for countries that participated in more rounds of tariff negotiations. This again provides little support to the idea that formal rules are the main driver of reciprocity uncovered in Figure 3.

4.4 Sensitivity Analysis

Time-series evidence. The estimates of welfare weights $\{\beta_{ij}\}$ reported so far have been obtained from global tariffs in 2001, just as the WTO’s crowning achievement, the Uruguay Round, was fully phased in. In this section we go further and ask whether the pattern of international cooperation documented earlier can be observed over time.

To explore this issue, we apply the same procedure as above separately to data from every year for the two decades of 1997-2019. This draws on dynamic versions of the sources described in Section 3.2—namely, annual records on tariffs from TRAINS, product-level trade flows from BACI, and sector-level inputs from ICIO.²³ Armed with such data

²¹We obtain these variables from the CEPII gravity dataset in 2001. For regions that contain multiple countries, we use the population-weighted average for each exporter-importer pair.

²²The estimated relationship between $\hat{\beta}_{ij}$ and $\hat{\beta}_{ji}$ is also robust to controlling for exporter and imported fixed effects. In such a specification, the point estimate is 0.21 with a standard error of 0.036.

²³We also use the replication package from Fajgelbaum et al. (2024) to obtain the tariffs applied by the US and China during their trade war in 2018 and 2019.

Table 2: Sensitivity I: Time-Series Evidence

	(1)	(2)	(3)	(4)
<i>Panel (a):</i> Dependent variable $\hat{\beta}_{ij,t}$				
$\hat{\beta}_{ji,t}$	0.277*** (0.029)	0.170*** (0.020)	0.115*** (0.018)	0.103*** (0.017)
Observations	17,896	17,896	17,896	17,735
R^2	0.174	0.615	0.745	0.753
<i>Panel (b):</i> Dependent variable $t_{ij,t}$				
$t_{ji,t}$	0.048** (0.022)	0.015 (0.013)	0.006 (0.011)	0.012 (0.011)
Observations	17,828	17,828	17,828	17,667
R^2	0.058	0.632	0.756	0.763
Year fixed effects	Yes	Yes	Yes	Yes
Exporter-importer fixed effects	No	Yes	Yes	Yes
Exporter-importer time trends	No	No	Yes	Yes
Controls from column (4) of Table 1	No	No	No	Yes

Notes: Panel (a) of this table reports regressions of estimated welfare weights $\hat{\beta}_{ij,t}$, for all pairs of exporters j and importers i , and all years t from 1997-2019 on $\hat{\beta}_{ji,t}$ and the controls indicated. Panel (b) is analogous but the dependent variable, $t_{ij,t}$ is the average (import-weighted across products in the counterfactual free trade equilibrium) import tariff that j imposes on country i in year t and the regressor is $t_{ji,t}$, the average (export-weighted across products in the counterfactual free trade equilibrium) import tariff that country i imposes on country j in year t .

we then re-compute the values of the regressors $\{\partial\omega_{i,t}/\partial m_{gj,t}\}$ in each year t , and estimate the weights $\{\beta_{ij,t}\}$ by estimation equation (23) separately, year by year.

The time path of the welfare weights that we estimate is summarized in Appendix Figure B.8. Echoing the results of Ritel (2024), we find that there is evidence for growing cooperation in the world trading system throughout this time period, with the average welfare weight rising from 0.81 in 2001 to 0.89 in 2007 and then flattening to 0.92 in 2014-2019.²⁴ We also find that this rise in as-if altruism is accompanied by a halving in the global standard deviation in $\hat{\beta}_{ij,t}$. Using the estimates of welfare weights $\{\hat{\beta}_{ij,t}\}$ for all years from 1997 to 2019, Table 2 shows that the conclusions from Table 1 about the importance of reciprocity in international cooperation continue to hold in the time series. As can be seen from Panel (a), this is true even after adding controls for year dummies, exporter-importer dummies, and exporter-importer time trends, though the estimated coefficient on $\hat{\beta}_{ji,t}$ goes down to 0.103 in the most stringent specification. Like in the cross-section, we see from Panel (b) that no such reciprocal pattern holds for tariffs.²⁵

²⁴This is qualitatively similar to, but quantitatively different from, the findings of Ritel (2024) who concludes that global trade cooperation increased by 265% over the last three decades.

²⁵This stark difference can also be visualized in Appendix Figures B.9 and B.10, which provide the counterpart of Figure 3 for changes in welfare weights and tariffs, separately for the periods before and after the US-China trade war.

As a final illustration of reciprocity unfolding over time, now in the form of a bad for a bad, Appendix Figure B.11 reports the evolution of the US and Chinese welfare weights. Before the US-China trade war, the time path of the weights that both countries placed on each other was similar to the value that they placed on other countries, and close to 0.9 in 2017. This changes dramatically in 2018 and 2019. Bilateral weights of the United States and China collapse to around 0.5, while other weights remain roughly constant.

Domestic redistribution. In our baseline analysis, we have abstracted from domestic redistribution. In order to bring such considerations into our analysis, we consider a variation of our quantitative model in which we let workers be immobile across three broad sectoral groups (agriculture-and-mining, manufacturing, and services) rather than fully mobile across sectors. This implies that wages may now vary both across countries and sectoral groups. All other assumptions are unchanged.

In this environment, a country may also choose its tariffs in order to help domestic or foreign workers from a subset of sectors at the expense of others, as described in equation (12). We now explore whether the introduction of such considerations affects our previous conclusions. We start by re-computing the values of the regressors $\{\partial\omega_i/\partial m_{gj}\}$ in this alternative quantitative model (calibrated to 2001). We then re-estimate the weights $\{\beta_{ij}\}$ using equation (12) applied to 2001 tariff data, but now including the extra terms $\partial(\omega_i(n) - \bar{\omega}_i)/\partial m_{gj}$ each corresponding to the sensitivity of real earnings of workers from country i in one of the three broad sectors n , either agriculture-and-mining, manufacturing or services. Despite adding these $3 \times 28 = 84$ additional regressors to our estimating equation, the relationship between these new welfare weights and our baseline ones is a close one, as can be seen in Appendix Figure B.13. Consequently, when we project these new weights on the full set of regressors in column (4) of Table 1—as shown in Table 3 column (2)—we observe a pattern of reciprocity that is, if anything, stronger than that in our baseline (repeated in column 1).²⁶

Alternative calibration. For our final robustness checks, we go back to our baseline model, and again use 2001 data, but consider alternative calibrations of the model’s key elasticities before again computing the regressors $\{\partial\omega_i/\partial m_{gj}\}$ and estimating the weights $\{\beta_{ij}\}$. In the first exercise, we raise the values of κ , η , and σ from their baseline values of 1.19, 1.53 and 2.53, respectively, to values of $\kappa = \eta = \sigma = 2.53$. In the second one, we raise them to $\kappa = \eta = \sigma = 4.0$. As we depart from our baseline calibration, the

²⁶The coefficients on other covariates from column (4) of Table 1 are also similar. We report those in Appendix Table B.2.

Table 3: Sensitivity II: Domestic Redistribution and Alternative Calibration

	Dependent variable: $\hat{\beta}_{ij}$			
	(1)	(2)	(3)	(4)
$\hat{\beta}_{ji}$	0.192*** (0.038)	0.419*** (0.042)	0.231*** (0.038)	0.167*** (0.032)
Observations	784	784	784	784
R^2	0.293	0.377	0.307	0.283
Specification	Baseline	Redistrib. controls	$\kappa = \eta = \sigma = 2.53$	$\kappa = \eta = \sigma = 4$

Notes: This table examines the sensitivity of our analysis of reciprocal behavior in tariff-setting (as reported in Table 1) to alternative economic models that give rise to alternative estimates $\hat{\beta}_{ij}$. All specifications control for the regressors included in column (4) of Table 1. The values of $\hat{\beta}_{ij}$ used in column (1) are from our baseline (i.e. column 4 of Table 1). Those used in column (2) are from a version of equation (23) that adds controls for each $\partial(\omega_i(n) - \bar{\omega}_i)/\partial m_{gj}$ across all pairs of exporters i and broad sectors n . And those used in columns (3) and (4) are from a version of equation (23) with an alternative calibration of the elasticities in the economic model.

implied values of opportunistic tariffs \hat{t}_{gj} fall, going from a median value of 55% (in ad-valorem terms) to 44% and 24%, as described in Appendix Figure B.14. Nevertheless the correlation between baseline and new opportunistic tariffs is above 0.75. Similarly, the new welfare weights that we estimate remain strongly correlated with our baseline values, as can be seen from Appendix Figures B.15 and B.16. This leads to a similar pattern of reciprocity in columns (3) and (4) of Table 3.

5 How Large Are the Gains from Reciprocity?

In the previous section, we have provided evidence of international cooperation being sustained by a general form of reciprocity among nations: cooperative behavior by one country, in the form of a higher welfare weight, is reciprocated with cooperative behavior by its partner, also in the form of a higher welfare weight. We now conclude our analysis by exploring the extent to which countries may benefit from such cooperation.

As emphasized in our introduction, one limitation of our empirical strategy is that it does not allow us to consider counterfactual exercises where welfare weights may endogenously change. That is, we have offered direct evidence on the extent to which countries internalize the impact of their trade policies onto others and we have shown that formal trade agreements cannot account for this pattern of international cooperation. But our analysis is silent, for instance, about how welfare weights and self-enforcing tariffs would change if countries were to switch from one equilibrium of a dynamic tariff game, that features reciprocity, to another, that does not.

In future work, one might imagine fully specifying such a dynamic game and leverag-

ing its exact structure, together with our estimates of welfare weights, to provide insights about the gains from international cooperation.²⁷ More modestly here, we propose to take a first pass at evaluating the potential gains from reciprocity by treating the welfare weights β_{ij} as exogenous and ask: Everything else being equal, how different would the welfare of a given country j be in a counterfactual world where it stops internalizing the impact of its trade policies onto others, i.e. $\beta_{ij} = 0$ for all $i \neq j$ rather than its estimated value $\hat{\beta}_{ij}$, and others stop internalizing the impact of their policies on country j , i.e. $\beta_{ji} = 0$ for all $i \neq j$ rather than its estimated value $\hat{\beta}_{ji}$?

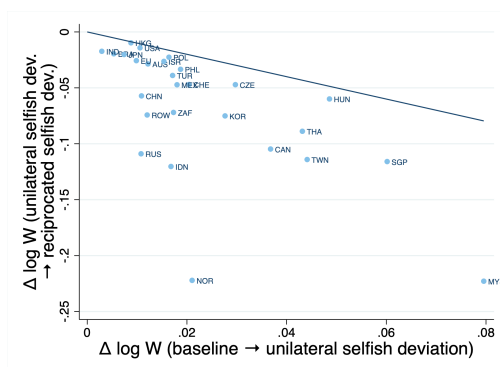
We answer this question by using our general formula to compute counterfactual tariffs iteratively for each of the 28 exercises in which one country j stops giving and receiving non-zero welfare weights. This is possible despite the high dimensionality of the environment that we consider relative to previous quantitative work on the gains from international cooperation; we let 28 countries choose a total of 217,454 tariff lines, whereas Ossa (2014), for instance, lets 7 countries choose a total of 231 tariff lines. Figure 4 displays the associated real consumption gains for each exercise. That is, each dot in this figure is a separate simulation, centered on the fate of country j , one at a time. On the x-axis, we report the welfare change experienced by each country j as welfare weights go from $\beta_{ji} = \hat{\beta}_{ji}$ to $\beta_{ji} = 0$, i.e. as country j stops cooperating with the rest of the world. On the y-axis, we report the welfare change experienced by each country j as welfare weights further go from $\beta_{ij} = \hat{\beta}_{ij}$ to $\beta_{ij} = 0$, i.e. as the world stops cooperating with country j . Country j 's total gains from international cooperation via reciprocity are equal to (the opposite of) the sum of these two welfare changes. In both cases, we hold ad-valorem tariffs fixed in all bilateral relationships whose welfare weights do not change.²⁸

Our main finding here is that all observations in Figure 4 lie below the -45 degree line. This implies gains from reciprocity for all countries—i.e. the gains from opportunistic deviations are overcome by the losses of being punished for such deviations. These gains are also larger for countries who gain more from opportunistic deviations (i.e. have larger x-axis values), consistent with the idea that more cooperative countries are rewarded by their trading partners. In terms of magnitude, the median gain from reciprocity is 5.2%. To put this number in perspective, going from Nash tariffs—that obtain when *all* countries act opportunistically vis-a-vis *all* trading partners, i.e. $\beta_{ij} = 0$ for all j and $i \neq j$ —to the observed tariffs would cause a median gain of 1.3%, whereas going from the observed tariffs to free trade would cause a further median gain of 0.1%.

²⁷This would amount to providing the formal mapping between countries' equilibrium strategies and the endogenous Lagrange multipliers $\{\lambda_{ij}\}$ in Section 2.2.

²⁸We also assume that when a country updates its tariffs, it holds fixed their "residual" component corresponding to ϵ_{gj} in equation (23).

Figure 4: Gains from Reciprocity



Notes: This figure reports for each country j the welfare change associated with a counterfactual scenario in which (i) country j 's welfare weights go from $\hat{\beta}_{ij}$ to zero and (ii) other countries' welfare weights go from $\hat{\beta}_{ji}$ to zero. The welfare change associated with (i) is reported on the x-axis, whereas the welfare change associated with (ii) is reported on the y-axis. Gains from reciprocity are equal to (the opposite of) the sum of these two welfare changes. The figure omits Saudi Arabia, which is an outlier with very large gains from reciprocity.

6 Concluding Remarks

We have used global tariffs to reveal the weights that nations implicitly place on the welfare of their trading partners relative to their own. Our estimated welfare weights suggest that formal and informal rules of the world trading system make countries internalize the impact of their policies onto others to a substantial extent, though not fully. On average, the value of one dollar transferred to another country is 19% lower than the value of that same dollar transferred to a country's own residents. Across nations, we find that countries that put more weights on the welfare of foreigners also tends to receive higher welfare weights from them. Our results are consistent with international cooperation being sustained by a general form of reciprocity among nations: cooperative behavior by one country, in the form of a higher welfare weight, is reciprocated with cooperative behavior by its partner, also in the form of a higher welfare weight. This is true both within and outside the World Trade Organization.

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A Data Appendix

This appendix provides details about data sources and measurement of the variables used throughout the paper.

A.1 Data for Model Calibration

We begin by describing the data sources and methodology that we adopt to measure the variables used to calibrate the model. All data is for the year 2001. We define the set of trading partners in the world \mathcal{I} as the European Union (EU), which includes its 15 members in 2001, plus 26 other countries in the OECD ICIO database (see Table A.1). We aggregate all remaining countries in a rest-of-the-world composite. Our sector classification contains 44 sectors \mathcal{S} based on the ICIO's categories (see Table A.2). Our product set $\mathcal{H} \equiv \cup_{s \in \mathcal{S}} \mathcal{H}_s$ consists of the 5,113 products that populate the 6-digit HS (revision 1) categories, plus a set of fictitious sector-specific products used to accommodate differences between data sources.

We now describe how we build the variables used in calibration from various available datasets.

Global Sector-Level Input-Output Tables. We begin with the OECD's ICIO database for 2001. This source measures the flow of goods and services from any origin country-sector (in $\mathcal{I} \times \mathcal{S}$) to any destination country-sector around the globe. The 27 trading partners in our sample tend to be large and relatively high-income, and together represent 91% of world trade in 2001. The ICIO sector categories are based on minor aggregations of ISIC revision 4 categories.

For every sector and trade partner, we use the ICIO database to compute gross output, Y_{is}^{ICIO} , and intermediate spending on goods from other sector (from all origins), I_{iks}^{ICIO} . From the ICIO database, we also obtain final spending of each country i on different sectors (from all origins), F_{is}^{ICIO} .²⁹ Finally, we obtain from the ICIO database bilateral trade flows between any two country-sector pairs, which we aggregate across sectors of a destination to obtain bilateral trade flows of goods from sector s of origin i to destination j (for either final or intermediate consumption), X_{ijs}^{ICIO} .

²⁹We define final spending in each country-sector as the sum across all origins for that sector of five categories of final demand: private consumption, non-profit consumption, government consumption, investment, and direct purchases abroad.

Table A.1: List of countries in the ICIO sample

Groups of world regions	
Countries	European Union (EU)
Australia	Austria
Brazil	Belgium-Luxembourg
Canada	Denmark
China	Finland
Chinese Taipei	France
Czech Republic	Germany
Hong Kong, China	Greece
Hungary	Ireland
India	Italy
Indonesia	Netherlands
Israel	Portugal
Japan	Spain
Korea	Sweden
Malaysia	United Kingdom
Mexico	
Norway	
Philippines	
Poland	
Russian Federation	
Saudi Arabia	
Singapore	
South Africa	
Switzerland	
Thailand	
Türkiye	
United States	

Crosswalk from 6-digit HS (rev 1) to ICIO categories. We also build a crosswalk from 6-digit HS (revision 1) to the ICIO sectors that are based on ISIC revision 4 categories. To this end, we use the OECD crosswalk from 6-digit HS (rev 1) to their category “Desci4” (based on ISIC rev 4) and then to the ICIO sectors.³⁰ We manually assign three products in Desci4 “Waste” to the sector including waste management, and twelve products in Desci4 “Others” to the sector “Other manufacturing.” Finally, since HS codes cover merchandise trade, we reclassify 28 products initially mapped to the service sector “Publishing, audiovisual and broadcasting activities” into the manufacturing sector “Paper and printing products.”

International Trade Flows. We use the CEPII BACI database to measure FOB trade flows among all countries, broken down by 6-digit HS (rev 1) product. We aggregate

³⁰The crosswalk from H1 to Desci4 is available in [link](#), and the crosswalk from Desci4 to ICIO sectors is available in this [link](#).

Table A.2: List of sectors in the ICIO sample

Agriculture, hunting	Fishing and aquaculture	Mining, energy producing
Mining, non-energy producing	Mining support services	Food, beverages, tobacco
Textiles, leather	Wood, products of wood and cork	Paper products and printing
Coke and refined petroleum	Chemicals and pharmaceuticals	Rubber and plastics products
Other non-metallic mineral pr.	Basic metals	Fabricated metal products
Computer and electronic eq.	Electrical equipment	Machinery and equipment, nec
Motor vehicles, trailers	Other transport equipment	Manufacturing; repair, installation
Electricity, gas, steam	Water supply, sewerage	Construction
Wholesale and retail trade	Land transport and via pipelines	Water transport
Air transport	Warehousing, support transport.	Postal and courier
Accommodation, food service	Audiovisual and broadcasting	Telecommunications
IT and information services	Financial and insurance	Real estate
Professional and technical act.	Administrative and support services	Public administration, defence
Education	Human health, social work	Arts, entertainment
Other services	Activities of households; own use	

the countries in BACI to those in our sample by summing trade flows among the countries associated with each trade partner. We let $\tilde{X}_{ijh}^{\text{BACI}}$ denote (pre-tax) trade flows of product h from origin i to destination j obtained from BACI for our sample of trading partners. We then rescale all bilateral BACI product-level flows such that the implied sector-level aggregates (within each pair) equals the corresponding flow in ICIO. Formally, we compute adjusted (post-tariff) trade flows from BACI as $X_{ijh}^{\text{BACI}} \equiv (1 + t_{ijh}^{\text{av}}) \tilde{X}_{ijh}^{\text{BACI}} X_{ijk}^{\text{ICIO}} / \left(\sum_{v \in \mathcal{H}_k} \tilde{X}_{ijv}^{\text{BACI}} \right)$, where t_{ijh}^{av} is the ad-valorem equivalent import tariff that we describe below. In addition, we create fictitious product h_s^* in each sector such that we impute the adjusted (post-tariff) trade flow to be $X_{ijh_s^*}^{\text{BACI}} = (1 + t_{ijh}^{\text{av}}) X_{ijk}^{\text{ICIO}} \mathbb{I}[\sum_{v \in \mathcal{H}_k} \tilde{X}_{ijv}^{\text{BACI}} = 0]$. In other words, for every origin-destination-sector triplet for which $\sum_{v \in \mathcal{H}_k} \tilde{X}_{ijv}^{\text{BACI}} = 0$ and $X_{ijk}^{\text{ICIO}} > 0$, we use the sector-specific fictitious product to match sector-level bilateral flows reported in ICIO. Note that this fictitious product accounts for all triplets not covered by BACI; in particular, domestic trade flows in all sectors and international trade flows in non-merchandise sectors.

Import Tariffs. We obtain tariff data from the UNCTAD TRAINS database (accessed via WITS). This source tracks the tariffs charged by a growing set of countries in the world (but one that is relatively complete by 2001), from 1988 to the present. For any importing country, the TRAINS database collects all of the tariff files that the importer makes available. Such files come in two formats. The first is the importer’s applied “MFN” tariff, where the term “MFN” is used regardless of whether the importer is a WTO member at the time of filing or not. And the second format reflects each of the preferential

trade agreements (PTAs) of which the importer is a member. Here, the term “PTA” is used broadly, to reflect free trade areas, customs unions, and multilateral schemes such as the Generalized System of Preferences that favors low-income countries. Both types of files are available in ad-valorem equivalent (AVE) terms—that is, in cases where the underlying tariff is specific or mixed, TRAINS uses HS 6-digit level price data to convert everything into AVE form. Finally, for the case of the United States, we augment the set of PTAs in TRAINS to include one additional and artificial “PTA,” which is the discriminatory “column two” tariff that the US charges on certain origin countries (Afghanistan, Cuba, Laos, North Korea, Serbia, and Vietnam, as of 2001).³¹

Given this set of files concerning any given importer’s tariff rates that are available in TRAINS in 2001, one could simply assign the PTA rate to all of the members of each PTA in question, and then assign the MFN rate to all other origin countries. However, the TRAINS database has incomplete coverage of both MFN and PTA files for many countries in any given year (such as 2001). As a result, such a procedure would result in missing values (when neither the MFN nor PTA file is available). And as highlighted by Teti (2023), such a procedure would also result in erroneous application of the typically higher MFN rate to country pairs for which a lower PTA tariff is actually applicable; that is, the absence of a given PTA’s file for a given importer-year in TRAINS is not necessarily indicative of the absence of the PTA itself.

To overcome these potential sources of bias, we follow the interpolation procedure developed by Teti (2023) and Caliendo et al. (2023). That is, in general we assume that when a tariff file (MFN or PTA) is missing for given importer-year, the best proxy for the true tariff in question is the most recent preceding year in which the relevant tariff file is available. However, we make two exceptions to this principle. First, in some rare cases the importer’s first MFN file appears after 2001, and in these cases we use the first available file as a proxy for the 2001 file. And second, when the importer in question joined the WTO at some date between 2001 and its most recent preceding MFN file date, we then instead use the most recent subsequently available MFN file.³² Execution of this interpolation procedure requires us to concord 6-digit HS products across revisions, which we do via the concordance tables provided by WITS.

A secondary type of missing information in TRAINS occurs when an MFN tariff file is available but contains missing tariff information for certain products, which happens for 0.4% of the exporter-importer-product triplets in our dataset. In this case we fill in

³¹We obtain these data from USITC files, accessed via Pete Schott’s website.

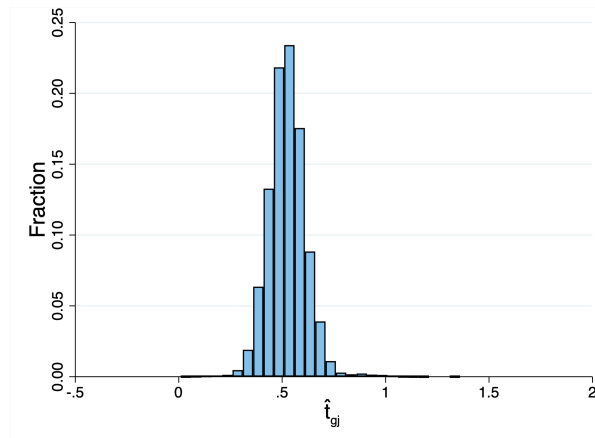
³²The general preference for preceding tariff files follows from the fact that importers are more likely to submit a file to TRAINS when its tariffs change. However, we make an exception for WTO-joiners since importers are likely to have changed their tariffs upon their WTO accession.

the missing 6-digit HS product information with the average tariff for the importer-origin pair among products within either the corresponding 4-digit, 2-digit or ICIO sector depending on availability of non-missing tariff information.

The result of the above procedure is a complete set of AVE tariffs for all pairs of countries and all 6-digit HS products as of 2001. We then collapse this dataset over all of the constituent members of the rest-of-the-world group by taking the simple average within each product.

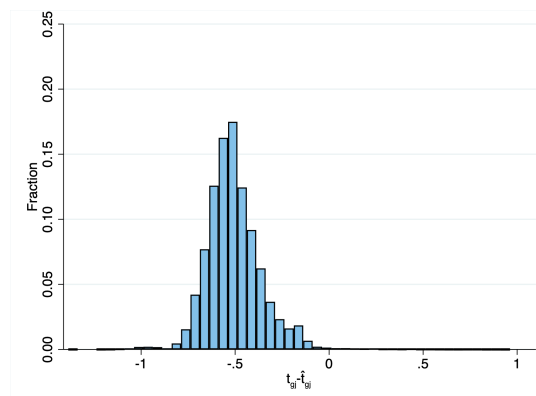
B Estimation Appendix

Figure B.1: Opportunistic Tariffs



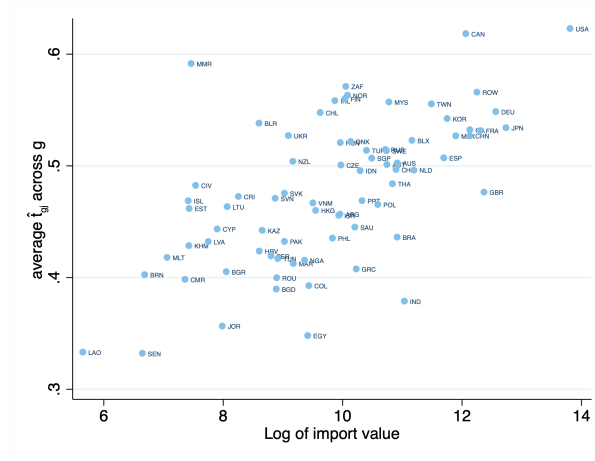
Notes: Figure B.1 plots the distribution of opportunistic tariffs \hat{t}_{gj} across all importers j and goods g in our estimation sample.

Figure B.2: Opportunistic Tariffs vs. Observed Tariffs



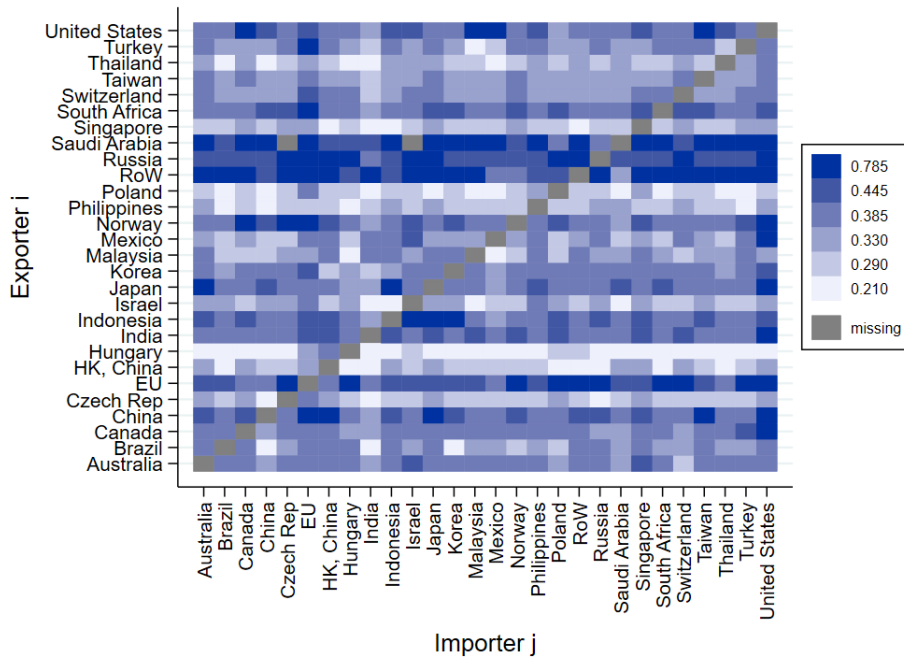
Notes: This figure plots the distribution of the difference between observed and opportunistic tariffs (i.e. $t_{gj} - \hat{t}_{gj}$) across all importers j and goods g in our estimation sample.

Figure B.3: Opportunistic Tariffs and Importer Size



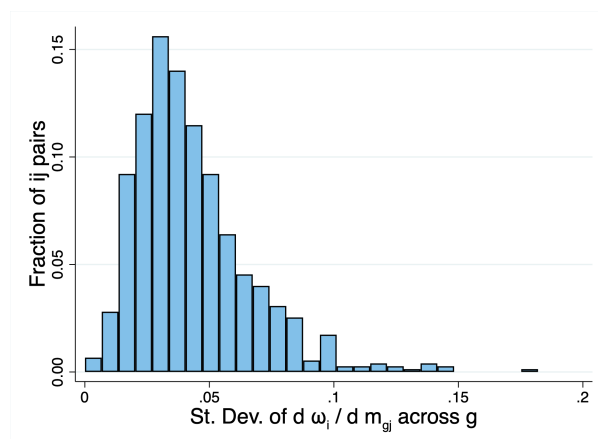
Notes: This figure reports the mean value of the opportunistic tariff $\hat{t}_{g,j}$, taken across all goods g , on the y-axis against the log of the total value of imports of a given importer j on the x-axis.

Figure B.4: Sensitivity of Foreign Real Income to Changes in Imports



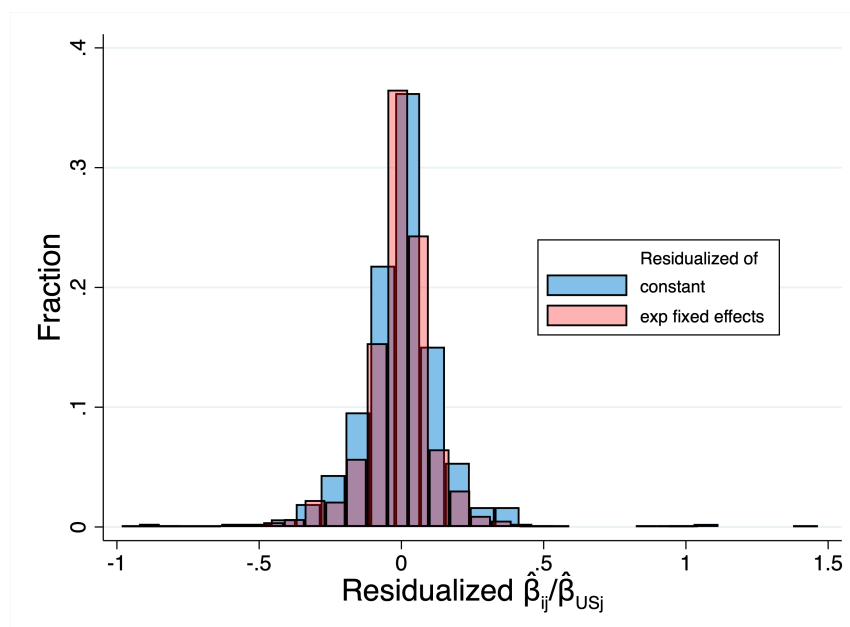
Notes: This figure plots for each origin country i on the y-axis and each destination country j on the x-axis, the mean of $\partial\omega_i/\partial m_{g,j}$ (in dollars per dollar of imports) across all goods $g = (i, j, h)$ that account for 95% of j 's import value in 2001. The entries along the diagonal as well as those with zero trade in our sample are omitted (shaded gray).

Figure B.5: Standard Deviation of Sensitivity of Foreign Real Income to Changes in Imports



Notes: Figure B.5 reports the distribution, across all origin-destination pairs (i, j) , of the standard deviation of $\partial\omega_i/\partial m_{gj}$ across all goods g .

Figure B.6: Are Tariffs Pareto Efficient?



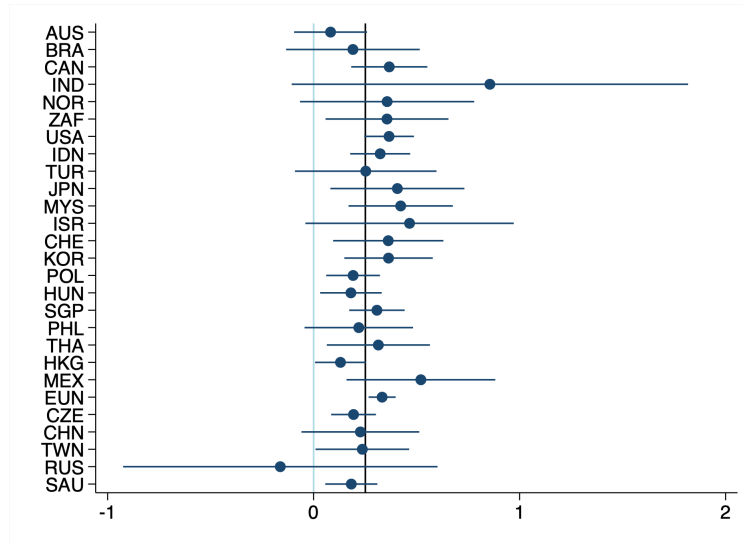
Notes: Figure B.6 plots the distribution of $\hat{\beta}_{ij}/\hat{\beta}_{USj}$ both after residualizing for a constant and for exporter fixed effects. Under Pareto efficiency, the latter distribution should display no variance, whereas in practice it shows just as much variance as the former distribution.

Table B.1: Are Tariffs Pareto Efficient?

	avg.	avg.	sd.	p-value	
	$\frac{\beta_{jj}}{\beta_{USj}}$	$\frac{\beta_{ij}}{\beta_{USj}}$	$\frac{\beta_{ij}}{\beta_{USj}}$	$\frac{\beta_{jj}}{\beta_{USj}} = k_i$ for all i	$\frac{\beta_{ij}}{\beta_{USj}} = k_i$ for $i \neq j$
AUS	1.21	0.92	0.22	0.00	0.00
BRA	1.42	0.91	0.13	0.00	0.00
CAN	1.03	0.96	0.11	0.00	0.00
CHN	1.37	0.87	0.08	0.00	0.00
TWN	1.14	0.95	0.09	0.00	0.00
CZE	1.10	0.96	0.22	0.00	0.00
EUN	1.12	1.00	0.09	0.00	0.00
HKG	1.05	0.90	0.22	0.00	0.00
HUN	1.30	0.93	0.18	0.00	0.00
IND	2.43	0.77	0.07	0.00	0.00
IDN	1.16	0.98	0.10	0.00	0.00
ISR	1.01	1.00	0.15	0.00	0.00
JPN	1.12	0.98	0.07	0.00	0.00
KOR	1.18	0.90	0.08	0.00	0.00
MYS	1.14	0.96	0.09	0.00	0.00
MEX	1.14	0.95	0.10	0.00	0.00
NOR	1.10	1.07	0.11	0.00	0.00
PHL	1.20	0.94	0.22	0.00	0.00
POL	1.32	1.01	0.29	0.00	0.00
ROW	1.30	0.89	0.08	0.00	0.00
RUS	1.19	0.97	0.08	0.00	0.00
SAU	1.34	1.06	0.29	0.00	0.00
SGP	1.02	1.06	0.09	0.00	0.00
ZAF	1.06	1.03	0.11	0.00	0.00
CHE	1.06	1.03	0.09	0.00	0.00
THA	1.30	0.88	0.10	0.00	0.00
TUR	1.11	0.95	0.12	0.00	0.00
USA	1.00	1.00	0.00	.	.
All	1.21	0.96	0.13	0.00	0.00

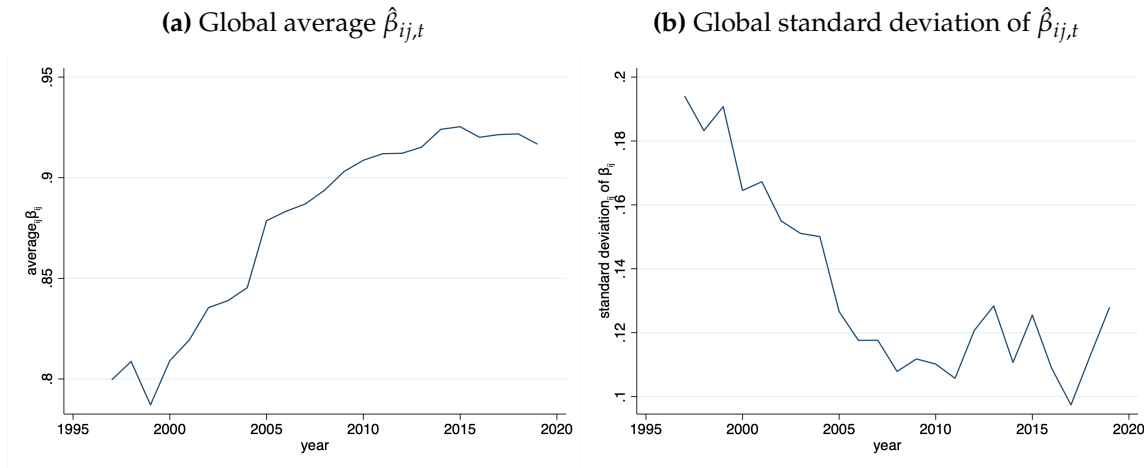
Notes: This table reports statistics based on the estimates of $\hat{\beta}_{ij}/\hat{\beta}_{USj}$ obtained from (23). For the exporter i listed in each row, column 1 reports i 's value for its own residents $\hat{\beta}_{ii}/\hat{\beta}_{USi}$, column 2 reports the average value that others place on i $\frac{1}{N-1} \sum_{j:j \neq i} \hat{\beta}_{ij}/\hat{\beta}_{USj}$, column 3 reports the standard deviation across importers j of their value for i , column 4 reports the p-value of the test $\hat{\beta}_{ij}/\hat{\beta}_{USj} = \beta_i$ for all WTO members j , and column 5 reports the p-value of the test $\hat{\beta}_{ij}/\hat{\beta}_{USj} = \beta_i$ for foreign countries that are WTO members. The last row reports the average of the statistic in the corresponding column across countries.

Figure B.7: Reciprocity in the World Trading System: Estimates By Each Importer



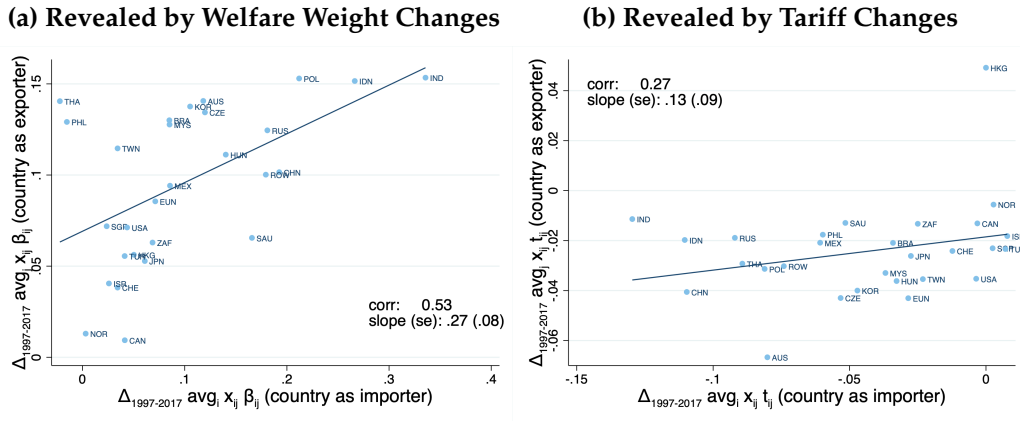
Notes: This figure reports the estimated slope of a regression of $\hat{\beta}_{ij}$ on $\hat{\beta}_{ji}$ (with a constant) separately for the importer listed in each row, with dots representing the point estimate and horizontal bars representing associated 95% confidence interval. Importers are ordered by the number of years of membership in WTO/GATT. The black vertical bar denotes the pooled estimate across all importers controlling for importer fixed effects. $\hat{\beta}_{ij}$ obtained from IV estimation of (23).

Figure B.8: Welfare Weights Over Time



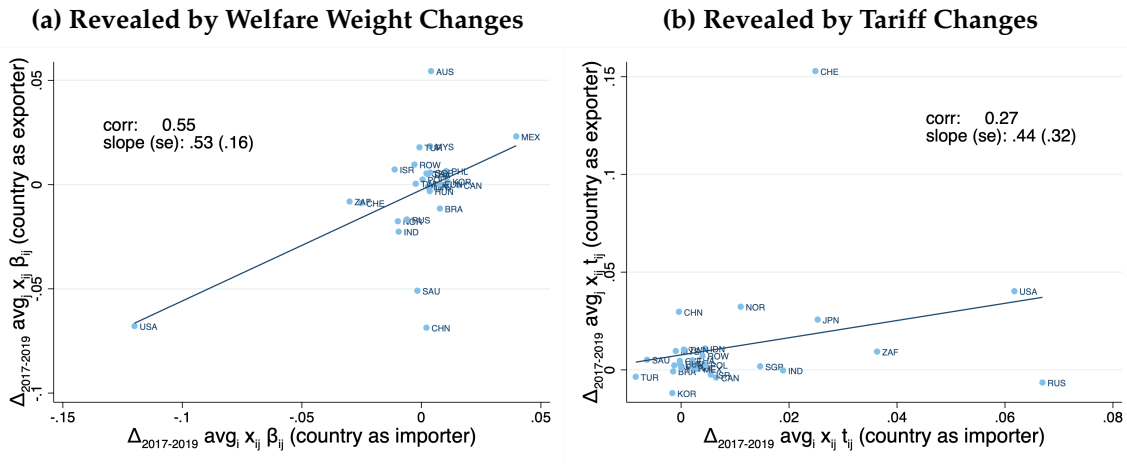
Notes: This figure describes changes in welfare weights from 1997 to 2019. In Figure B.8a, for each year t , we plot the global average of $\hat{\beta}_{ij,t}$, omitting values with $i = j$. Figure B.8b is analogous but for the standard deviation of $\hat{\beta}_{ij,t}$.

Figure B.9: Reciprocity in the World Trading System (1997-2017 Changes)



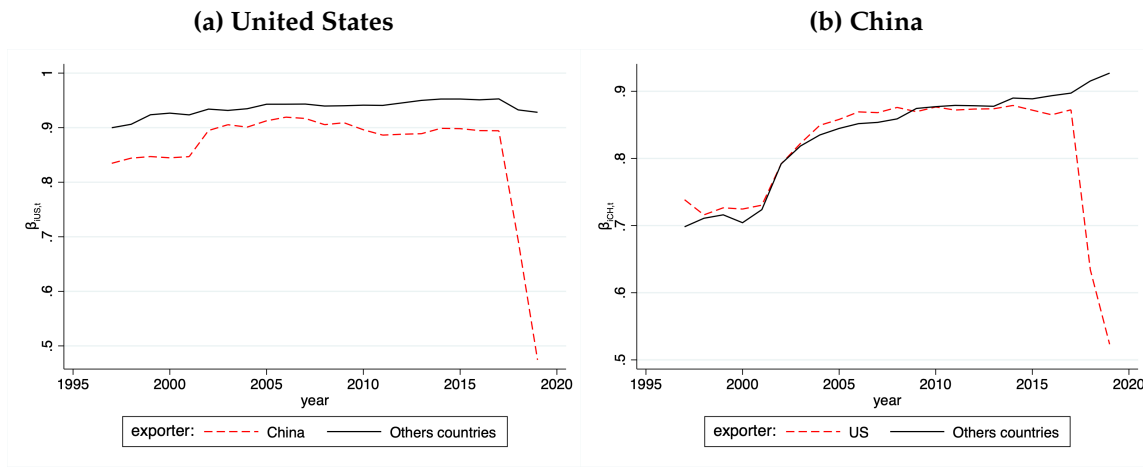
Notes: This figure assesses the extent of reciprocity in the world trading system over 1997-2017. In Figure B.9a, for each country j , we plot on the x-axis the average value of $\hat{\beta}_{ij,2017} - \hat{\beta}_{ij,1997}$ for all $i \neq j$, weighted by its imports in the year t counterfactual free trade equilibrium, against the average value of $\hat{\beta}_{ji,2017} - \hat{\beta}_{ji,1997}$, weighted by exports in the year t counterfactual free trade equilibrium on the y-axis. In Figure B.9b, for each country j , the x-axis is the 2017-1997 change in the average import tariff that j imposes on other countries and the y-axis is the 2017-1997 change in average tariff that other countries impose on j , weighted by imports and exports in the year t counterfactual free trade equilibrium, respectively.

Figure B.10: Reciprocity in the World Trading System (2017-2019 Changes)



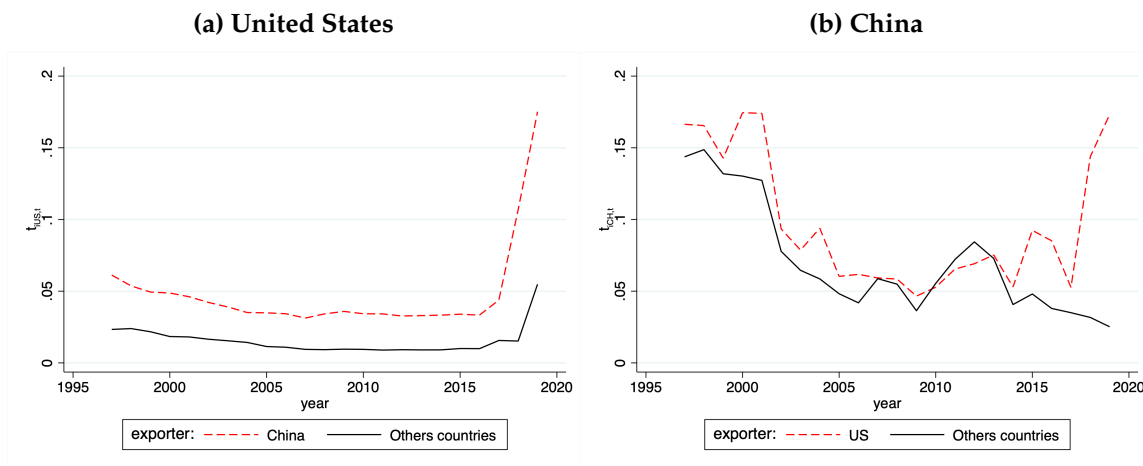
Notes: This figure assesses the extent of reciprocity in the world trading system over 2017-2019. In Figure B.10a, for each country j , we plot on the x-axis the average value of $\hat{\beta}_{ij,2019} - \hat{\beta}_{ij,2017}$ for all $i \neq j$, weighted by its imports in the year t counterfactual free trade equilibrium, against the average value of $\hat{\beta}_{ji,2019} - \hat{\beta}_{ji,2017}$, weighted by exports in the year t counterfactual free trade equilibrium on the y-axis. In Figure B.10b, for each country j , the x-axis is the 2019-2017 change in the average import tariff that j imposes on other countries and the y-axis is the 2019-2017 change in average tariff that other countries impose on j , weighted by imports and exports in the year t counterfactual free trade equilibrium, respectively.

Figure B.11: US and Chinese Welfare Weights Over Time



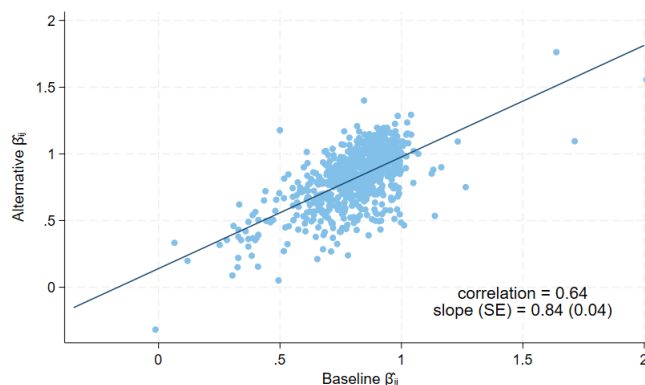
Notes: This figure describes changes in welfare weights $\hat{\beta}_{ij,t}$ for each year t from 1997 to 2019, for the United States (B.11a) and China (B.11b). When the exporter is “other countries,” we report the average of $\hat{\beta}_{ij,t}$ across other exporters weighted by imports in the counterfactual free trade equilibrium.

Figure B.12: US and Chinese Import Tariffs Over Time



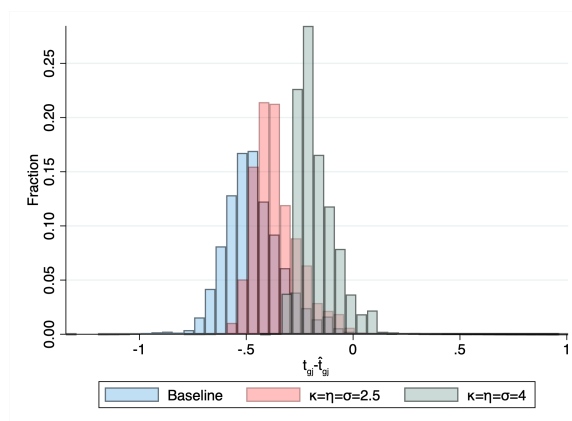
Notes: This figure describes changes in average impor tariff (weighted by imports in the counterfactual free trade equilibrium) for each year t from 1997 to 2019, for the United States (B.12a) and China (B.12b). When the exporter is “other countries,” we report the average import tariff across other exporters weighted by imports in the counterfactual free trade equilibrium.

Figure B.13: Sensitivity Analysis: Controls for Domestic Redistribution



Notes: This figure displays the relationship between the baseline estimates of $\hat{\beta}_{ij}$ in 2001 on the x-axis and estimated values obtained under an alternative procedure that controls for domestic redistribution motives in tariff-setting. The solid blue line illustrates the line of best fit.

Figure B.14



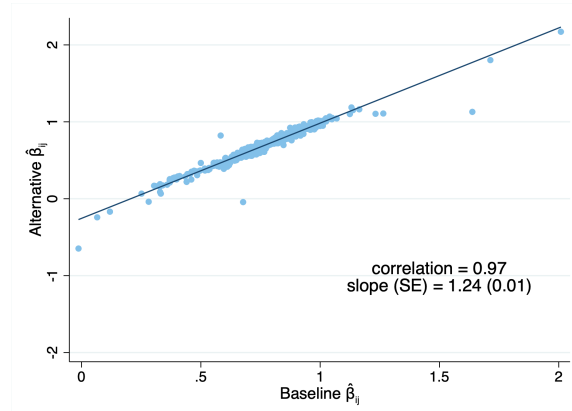
Notes: This figure plots the distribution of the difference between observed and opportunistic tariffs (i.e. $t_{gj} - \hat{t}_{gj}$) across all importers j and goods g in our estimation sample for different calibrations of the model parameters.

Table B.2: Sensitivity II: Domestic Redistribution and Alternative Calibration (Full Table)

	Dependent variable: $\hat{\beta}_{ij}$			
	(1)	(2)	(3)	(4)
$\hat{\beta}_{ji}$	0.192*** (0.038)	0.419*** (0.042)	0.231*** (0.038)	0.167*** (0.032)
$D\{i \in \text{WTO}, j \notin \text{WTO}\}$	-0.037** (0.018)	-0.125*** (0.024)	-0.047* (0.026)	-0.081* (0.042)
$D\{i \notin \text{WTO}, j \notin \text{WTO}\}$	0.064 (0.103)	0.034 (0.145)	0.024 (0.057)	0.010 (0.075)
$D\{i \notin \text{WTO}, j \in \text{WTO}\}$	0.037* (0.020)	0.060*** (0.022)	0.061** (0.024)	0.072* (0.040)
$D\{ij \text{ have pta}\}$	0.046*** (0.013)	0.044** (0.017)	0.052*** (0.017)	0.094*** (0.027)
log distance _{ij}	-0.017*** (0.002)	-0.007*** (0.003)	-0.022*** (0.003)	-0.038*** (0.004)
log population _i	-0.003 (0.006)	0.064*** (0.006)	-0.000 (0.007)	-0.002 (0.012)
log population _j	-0.031*** (0.005)	-0.020*** (0.007)	-0.043*** (0.007)	-0.075*** (0.011)
log p.c. income _i	0.017*** (0.006)	0.032*** (0.008)	0.025*** (0.008)	0.029** (0.013)
log p.c. income _j	0.030*** (0.007)	0.049*** (0.008)	0.032*** (0.009)	0.062*** (0.014)
Constant	0.792*** (0.039)	0.536*** (0.046)	0.757*** (0.040)	0.809*** (0.044)
Observations	784	784	784	784
R ²	0.293	0.377	0.307	0.283
Specification	Baseline	Redistrib. controls	$\kappa = \eta = \sigma = 2.53$	$\kappa = \eta = \sigma = 4$

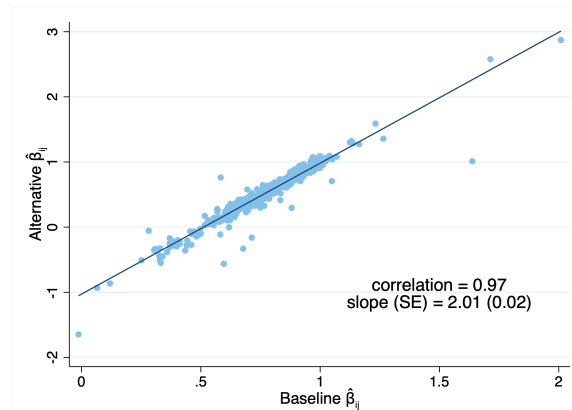
Notes: This table—the same as Table 3 but with all coefficients reported—examines the sensitivity of our analysis of reciprocal behavior in tariff-setting (as reported in Table 1) to alternative economic models. Column (1) repeats the baseline (i.e. column 4 of Table 1). Column (2) is based on estimates of $\hat{\beta}_{ij}$ obtained from estimating equation (23) while including controls for each $\partial(\omega_i(n) - \bar{\omega}_i)/\partial m_{gj}$ across all pairs of exporters i and broad sectors n . Columns (3) and (4) are based on estimates of $\hat{\beta}_{ij}$ obtained from estimating equation (23) when using an alternative calibration of the elasticities in the economic model.

Figure B.15: Sensitivity Analysis: Elasticities ($\kappa = \eta = \sigma = 2.53$)



Notes: This figure displays the relationship between the baseline estimates of $\hat{\beta}_{ij}$ in 2001 on the x-axis and estimated values obtained under an alternative procedure that re-solves the economic model at values of three key elasticities set to $\kappa = \eta = \sigma = 2.53$ (instead of $\kappa = 1.19$, $\eta = 1.53$ and $\sigma = 2.53$ in the baseline). The solid blue line illustrates the line of best fit.

Figure B.16: Sensitivity Analysis: Elasticities ($\kappa = \eta = \sigma = 4.0$)



Notes: This figure displays the relationship between the baseline estimates of $\hat{\beta}_{ij}$ in 2001 on the x-axis and estimated values obtained under an alternative procedure that re-solves the economic model at values of three key elasticities set to $\kappa = \eta = \sigma = 4.0$ (instead of $\kappa = 1.19$, $\eta = 1.53$ and $\sigma = 2.53$ in the baseline). The solid blue line illustrates the line of best fit.

C Quantitative Model

This appendix characterizes the competitive equilibrium of our economy (Section C.1), describes our calibration procedure (Section C.2), outlines an algorithm to solve the equilibrium given a set of trade taxes and exogenous parameters (Section C.3), and presents the expressions used to compute the sensitivity of terms of trade and tariff revenue to imports (Section C.4).

C.1 Equilibrium

Prices. Under perfect competition, Equations (15)-(18) imply that for all products $h \in \mathcal{H}_s$ shipped from origin country i to destination country j ,

$$p_{ijh} = p_{ijh}^w + t_{ijh} \quad (\text{C.1})$$

$$p_{ijh}^w = (\theta_{ijh})^{-1} p_{is} \quad (\text{C.2})$$

$$p_{is} = [\alpha_{is}]^{-\alpha_{is}} w_i^{\alpha_{is}} [1 - \alpha_{is}]^{-(1-\alpha_{is})} (p_{is}^M)^{1-\alpha_{is}} \quad (\text{C.3})$$

$$p_{is}^M = \prod_{k \in \mathcal{S}} [P_{ik}]^{\alpha_{iks}} \quad (\text{C.4})$$

$$P_{ik} = \left[\sum_{c=H,F} \theta_{ik}^c [P_{ik}^c]^{1-\kappa} \right]^{\frac{1}{1-\kappa}} \quad (\text{C.5})$$

$$P_{ik}^c = \left[\sum_{v \in \mathcal{H}_k} \theta_{ikv}^c [P_{ikv}^c]^{1-\eta} \right]^{\frac{1}{1-\eta}} \quad (\text{C.6})$$

$$P_{ikv}^c = \left[\sum_{o \in \mathcal{I}_i^c} \theta_{oikv}^c [p_{oiv}]^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \quad (\text{C.7})$$

where w_i is the price of labor in country i .

Bilateral Trade Flows. The expressions for prices in (C.1)-(C.7) and the expressions for technology and preferences in (15)-(18) and (19)-(22) imply that the (tariff-inclusive) spending in country $j \in \mathcal{I}$ on product $h \in \mathcal{H}_s$ in sector $s \in \mathcal{S}$ from Foreign country $i \in \mathcal{I}$

contained in origin group $c \in \{H, F\}$ is

$$X_{ijh} = \frac{\theta_{ijsh}^c [p_{ijh}]^{1-\sigma}}{[P_{jsh}^c]^{1-\sigma}} X_{jsh}^c \quad (\text{C.8})$$

$$X_{jsh}^c = \frac{\theta_{jsh}^c [P_{jsh}^c]^{1-\eta}}{[P_{js}^c]^{1-\eta}} X_{js}^c \quad (\text{C.9})$$

$$X_{js}^c = \frac{\theta_{js}^c [P_{js}^c]^{1-\kappa}}{[P_{js}]^{1-\kappa}} X_{js} \quad (\text{C.10})$$

where X_{js} is total expenditure on sector s by country j .

Input Demand. Equations (15)-(18) and the definition of P_{js} imply that the problem of the representative firm that produces a product $h \in \mathcal{H}_s$ within a sector $s \in \mathcal{S}$ in country $i \in \mathcal{I}$ for use in country $j \in \mathcal{I}$ can be written as

$$\max_{\ell_{ijh}, Q_{ik,ijh}} p_{ijh}^w \theta_{ijh} [\ell_{ijh}]^{\alpha_{is}} \left[\prod_{k \in \mathcal{S}} [Q_{ik,ijh} / \alpha_{iks}]^{\alpha_{iks}} \right]^{1-\alpha_{is}} - w_i \ell_i(f) - \sum_{k \in \mathcal{S}} P_{ik} Q_{ik,ijh}$$

This implies

$$\begin{aligned} w_i \ell_{ijh} &= \alpha_{is} Y_{ijh} \\ P_{ik} Q_{ik,ijh} &= \alpha_{iks} (1 - \alpha_{is}) Y_{ijh} \end{aligned}$$

where $Y_{ijh} = p_{ijh}^w q_{ijh}$ is the total revenue with sales of (i, j, h) .

Aggregating labor and input spending across all goods associated with the same sector and country then implies

$$W_{is} = \alpha_{is} Y_{is} \quad (\text{C.11})$$

$$I_{iks} = \alpha_{iks} (1 - \alpha_{is}) Y_{is} \quad (\text{C.12})$$

where $W_{is} \equiv w_i N_{is}$ —for N_{is} the labor employed in each sector s within country i —and $Y_{is} \equiv \sum_{h \in \mathcal{H}_s} \sum_{j \in \mathcal{I}} Y_{ijh}$ are the aggregate value added and revenue of all goods from sector s of origin i , and where $I_{iks} \equiv \sum_{h \in \mathcal{H}_s} \sum_{j \in \mathcal{I}} P_{ik} Q_{ik,ijh}$ is the aggregate expenditure of all such goods on intermediate inputs from sector k .

Final Demand. Equations (19)-(22) imply that final expenditure in country j on sector k is

$$F_{jk} = P_{jk}C_{jk} = \gamma_{jk}F_j \quad (\text{C.13})$$

where P_j^C denotes the consumption price index in j ,

$$P_j^C = \prod_{k \in \mathcal{S}} [P_{jk}]^{\gamma_{jk}}$$

and F_j denotes aggregate final spending in j , which must be equal to j 's aggregate income,

$$F_j = \sum_{s \in \mathcal{S}} W_{js} + \tau_j \quad (\text{C.14})$$

with

$$\tau_j = \sum_{k \in \mathcal{S}} \sum_{h \in \mathcal{H}_k} \sum_{o \in \mathcal{I}} \frac{t_{ojh}}{p_{ojh}} X_{ojh} + \phi_j \sum_{i \in \mathcal{I}, s \in \mathcal{S}} W_{is}. \quad (\text{C.15})$$

Market Clearing. Total spending of each country j on each sector k is

$$X_{jk} = F_{jk} + \sum_{s \in \mathcal{S}} \alpha_{jks} (1 - \alpha_{js}) Y_{js} \quad (\text{C.16})$$

Goods market clearing requires

$$Y_{is} = \sum_{j \in \mathcal{I}} \sum_{h \in \mathcal{H}_s} \frac{p_{ijh}^w}{p_{ijh}} X_{ijh} \quad (\text{C.17})$$

for all $i \in \mathcal{I}$ and $s \in \mathcal{S}$.

Labor market clearing requires

$$w_i N_i = \sum_{s \in \mathcal{S}} W_{is} \quad (\text{C.18})$$

for all $i \in \mathcal{I}$.

C.1.1 Solving for spending conditional on prices

It will be useful in solving the model to derive a linear equation that characterizes country-sector expenditures given prices. To begin, note that, given prices, (C.8)-(C.10) provide a linear expression for all trade flows in terms of country-sector expenditures: For any

countries $i, j \in \mathcal{I}$, sector $k \in \mathcal{S}$ and $h \in \mathcal{H}_k$,

$$X_{ijh} = \zeta_{ijkh} X_{jk} \quad (\text{C.19})$$

$$\text{where } \zeta_{ijkh} \equiv \begin{cases} \frac{\theta_{ijkh}^H [p_{ijh}]^{1-\sigma}}{[P_{jkh}^H]^{1-\sigma}} \frac{\theta_{jkh}^H [P_{jkh}^H]^{1-\eta}}{[P_{jk}^H]^{1-\eta}} \frac{\theta_{jk}^H [P_{jk}^H]^{1-\kappa}}{[P_{jk}^H]^{1-\kappa}} & \text{if } i = j \\ \frac{\theta_{ijkh}^F [p_{ijh}]^{1-\sigma}}{[P_{jkh}^F]^{1-\sigma}} \frac{\theta_{jkh}^F [P_{jkh}^F]^{1-\eta}}{[P_{jk}^F]^{1-\eta}} \frac{\theta_{jk}^F [P_{jk}^F]^{1-\kappa}}{[P_{jk}^F]^{1-\kappa}} & \text{if } i \neq j \end{cases} \quad (\text{C.20})$$

By (C.15), we similarly obtain a linear expression for tariff revenue, or equivalently, lump-sum transfers, in each country:

$$\tau_i N_i = \sum_{k \in \mathcal{S}} \kappa_{ik}^\tau X_{ik}$$

$$\text{where } \kappa_{ik}^\tau \equiv \sum_{o \in \mathcal{I}} \sum_{h \in \mathcal{H}_k} \frac{t_{ijh}}{p_{ijh}} \zeta_{oikh}$$

Similarly, (C.17) implies

$$Y_{is} = \sum_{j \in \mathcal{I}} \kappa_{ijs}^Y X_{js} \quad (\text{C.21})$$

$$\text{where } \kappa_{ijs}^Y = \sum_{h \in \mathcal{H}_s} \frac{p_{ijh}^w}{p_{ijh}} \zeta_{ijsh}$$

Applying these expressions to (C.16) and substituting for final spending using (C.13), (C.14), and (C.18) implies

$$X_{ik} = \sum_{j \in \mathcal{I}, s \in \mathcal{S}} e_{ik,js} X_{js} + E_{ik} \quad (\text{C.22})$$

$$\text{where } e_{ik,js} \equiv \mathbb{I}_{i=j} \gamma_{ik} \kappa_{is}^\tau + \alpha_{iks} (1 - \alpha_{is}) \kappa_{ijs}^Y$$

$$\text{and } E_{ik} \equiv \gamma_{ik} \left[w_i N_i + \phi_j \sum_{i \in \mathcal{I}} w_j N_j \right]$$

C.2 Calibration

We describe the calibration of $\{\alpha_{is}, \alpha_{iks}, \gamma_{js}, \theta_{ijh}, \theta_{ik}^c, \theta_{ikh}^c, \theta_{ijkh}^c, N_i, \phi_i\}$. We normalize to one all domestic prices ($p_{ijh} = 1$) and wages ($w_i = 1$) in the initial equilibrium. Equations (C.1)–(C.7) imply that

$$p_{js}^M = P_{jk} = P_{jk}^c = P_{jkh}^c = 1. \quad (\text{C.23})$$

Note that this normalization also implies that

$$t_{ijh} = t_{ijh}^{\text{av}} p_{ijh}^w = \frac{t_{ijh}^{\text{av}}}{1 + t_{ijh}^{\text{av}}} p_{ijh} = \frac{t_{ijh}^{\text{av}}}{1 + t_{ijh}^{\text{av}}} \quad (\text{C.24})$$

where t_{ijh}^{av} denotes the ad-valorem equivalent import tariff described in Section 3.2.

Sector-level Preference Shifters: $\{\gamma_{jk}\}$. Under the price normalization in (C.23), the expression for final demand C.13 implies that

$$\gamma_{jk} = \frac{F_{jk}^{\text{ICIO}}}{\sum_{s \in \mathcal{S}} F_{js}^{\text{ICIO}}}, \quad (\text{C.25})$$

with F_{jk}^{ICIO} denoting the final spending in sector k in country j reported in ICIO.

Sector-level Technology Shifters: $\{\alpha_{is}, \alpha_{iks}, \theta_{ijh}\}$. Under the price normalization in (C.23), the labor and intermediate demand in (C.11)-(C.12) imply that

$$\alpha_{is} = 1 - \frac{\sum_k I_{iks}^{\text{ICIO}}}{Y_{is}^{\text{ICIO}}} \quad (\text{C.26})$$

$$\alpha_{iks} = \frac{I_{iks}^{\text{ICIO}}}{\sum_{k \in \mathcal{S}} I_{iks}^{\text{ICIO}}}. \quad (\text{C.27})$$

with I_{iks}^{ICIO} and Y_{is}^{ICIO} denoting intermediate spending on sector k and gross output in sector s of country i reported in ICIO. Without loss of generality, we set $\alpha_{is} = 1$ when $Y_{is}^{\text{ICIO}} = 0$ and $\alpha_{iks} = 1/|\mathcal{S}|$ when $\alpha_{is} = 1$.

Since $p_{ijh} = 1$, $w_i = 1$, and $p_{is}^M = 1$, (C.1) implies that

$$\theta_{ijh} = (1 + t_{ijh}^{\text{av}}) [\alpha_{is}]^{-\alpha_{is}} [1 - \alpha_{is}]^{-(1-\alpha_{is})}.$$

Preference and Technology Shifters: $\{\theta_{ijkh}^c, \theta_{jkh}^c, \theta_{jk}^c\}$ From C.8, the normalization in (C.23) implies that

$$\theta_{ijkh}^c = \frac{X_{ijh}^{\text{BACI}}}{\sum_{o \in \mathcal{I}_j^c} X_{ijh}^{\text{BACI}}} \quad (\text{C.28})$$

with X_{ijh}^{BACI} denoting the adjusted (post-tariff) bilateral trade flows from i to j of product h that we described in Section A.1.

From C.9, the normalization in (C.23) implies that

$$\theta_{jkh}^c = \frac{\sum_{o \in \mathcal{I}_j^c} X_{ijh}^{\text{BACI}}}{\sum_{v \in \mathcal{H}_k} \sum_{o \in \mathcal{I}_j^c} X_{ijv}^{\text{BACI}}}. \quad (\text{C.29})$$

From C.10, the normalization in (C.23) implies that

$$\theta_{jk}^c = \frac{\sum_{v \in \mathcal{H}_k} \sum_{o \in \mathcal{I}_j^c} X_{ijv}^{\text{BACI}}}{\sum_{c=H,F} \sum_{v \in \mathcal{H}_k} \sum_{o \in \mathcal{I}_j^c} X_{ijv}^{\text{BACI}}}. \quad (\text{C.30})$$

Without loss of generality, we set $\theta_{ijkh}^c = 1/|\mathcal{I}_j^c|$ if $\sum_{o \in \mathcal{I}_j^c} X_{ojh}^{\text{BACI}} = 0$, $\theta_{jkh}^c = 1/|\mathcal{H}_k|$ if $\sum_{v \in \mathcal{H}_k} \sum_{o \in \mathcal{I}_j^c} X_{ijv}^{\text{BACI}} = 0$, and $\theta_{jk}^c = 1/2$ if $\sum_{c=H,F} \sum_{v \in \mathcal{H}_k} \sum_{o \in \mathcal{I}_j^c} X_{ijv}^{\text{BACI}} = 0$.

Country-level parameters: $\{N_i, \phi_i\}$. We now turn to the calibration of the labor endowment of each country under the normalization in (C.23). We use labor market condition in (C.18) to set the labor endowment as

$$N_i = \sum_{s \in \mathcal{S}} \alpha_{is} Y_{is}, \quad (\text{C.31})$$

where Y_{is} is the gross output in sector s of country i ,

$$Y_{is} = \sum_{h \in \mathcal{H}_s} \sum_{j \in \mathcal{I}^c} \frac{1}{1 + t_{ijh}^{\text{av}}} X_{ijh}. \quad (\text{C.32})$$

We obtain a measure of gross output that is consistent with the equilibrium conditions of the model using bilateral trade flows,

$$X_{ijh} \equiv \begin{cases} \theta_{ijkh}^H \theta_{jkh}^H \theta_{jk}^H X_{jk} & \text{if } i = j \\ \theta_{ijkh}^F \theta_{jkh}^F \theta_{jk}^F X_{jk} & \text{if } i \neq j \end{cases} \quad (\text{C.33})$$

where $\{\theta_{ijkh}^c, \theta_{jkh}^c, \theta_{jk}^c\}$ satisfy (C.28)-(C.30) and X_{jk} implied by

$$X = (I - M)^{-1} F^{\text{ICIO}} \quad (\text{C.34})$$

with $F = [F_{jk}^{\text{ICIO}}]$ the vector of final spending reported in ICIO and M the $(\mathcal{I} \times \mathcal{S}) \times (\mathcal{I} \times$

\mathcal{S}) matrix whose entries are given by

$$M_{ik,js} = (1 - \alpha_{is})\alpha_{iks} \sum_{h \in \mathcal{H}_s} \frac{1}{1 + t_{ijh}^{\text{av}}} \theta_{ijsh}^c \theta_{jsh}^c \theta_{js}^c.$$

Note that this guarantees that the the vector of gross spending satisfies the equilibrium system in (C.22).

Lastly, we set international transfers to satisfy the representative consumer's budget constrain in C.14:

$$\phi_i = \frac{\sum_{s \in \mathcal{S}} (X_{is} - Y_{is}) - \sum_{j \in \mathcal{I}} \sum_{s \in \mathcal{S}} \sum_{h \in \mathcal{H}_s} \frac{t_{jih}^{\text{av}}}{1 + t_{jih}^{\text{av}}} X_{jih}}{\sum_{j \in \mathcal{I}} N_j}, \quad (\text{C.35})$$

where $\{N_i, Y_{is}, X_{ik}, X_{ijh}\}$ are obtained from (C.31)-(C.34).

C.3 Numerical Algorithm for Equilibrium Computation

This section describes the algorithm that we use to compute equilibrium given any set of parameters and tariffs. We note that, because of the nested CES structure of demand in the model, it is easier to work with ad-valorem equivalent tariffs t_{ijh}^{av} . In this case, the equilibrium conditions above remain the same, but we specify $t_{ijh} = t_{ijh}^{\text{av}} p_{ijh}^w$ and thus $p_{ijh} = (1 + t_{ijh}^{\text{av}}) p_{ijh}^w$. We consider the following algorithm.

- i. We have an outer loop indexed by a . Guess $w_i^{a=0} = 1$ for all i .
- ii. Given w_i^a , we have an inner loop that solves for all prices and price indices $p_{ijh}^a, p_{is}^a, p_{is}^{M,a}, P_{jk}^a, P_{jk}^{c,a}, P_{jkh}^{c,a}$, and P_{jk}^C
 - (a) The inner loop is indexed by b . Guess $P_{jk}^{a,b=0} = 1$ if $a = 0$ and $P_{jk}^{a,b=0} = P_{jk}^{a-1}$ if $a > 0$.

(b) Using (C.1)-(C.7), we compute

$$\begin{aligned}
p_{is}^{M,a,b} &= \prod_{k \in \mathcal{S}} [P_{ik}^{a,b}]^{\alpha_{iks}} \\
p_{is}^{a,b} &= [\alpha_{is}]^{-\alpha_{is}} [w_i^{a,b}]^{\alpha_{is}} [1 - \alpha_{is}]^{-(1-\alpha_{is})} (p_{is}^{M,a,b})^{1-\alpha_{is}} \\
p_{ijh}^{a,b} &= (1 + t_{ijh}^{av}) (\theta_{ijh})^{-1} p_{is}^{a,b} \\
P_{jkh}^{c,a,b} &= \left[\sum_{i \in \mathcal{I}_j^c} \theta_{ijkh}^c [p_{ijh}^{a,b}]^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \\
P_{jk}^{c,a,b} &= \left[\sum_{h \in \mathcal{H}_s} \theta_{jkh}^c [P_{jkh}^{c,a,b}]^{1-\eta} \right]^{\frac{1}{1-\eta}} \\
\tilde{P}_{jk}^{c,b} &= \left[\sum_{c=H,F} \theta_{jk}^c [P_{jk}^{c,a,b}]^{1-\kappa} \right]^{\frac{1}{1-\kappa}}
\end{aligned}$$

(c) If $\max_{is} |P_{is}^{a,b} - \tilde{P}_{is}^{a,b}| < \text{tol}$, then we set $p_{ijh}^a = p_{ijh}^{a,b}$, $p_{is}^a = p_{is}^{a,b}$, $p_{is}^{M,a} = p_{is}^{M,a,b}$, $P_{jk}^a = P_{jk}^{a,b}$, $P_{jk}^{c,a} = P_{jk}^{c,a,b}$, and $P_{jkh}^{c,a} = P_{jkh}^{c,a,b}$. If not, then we set

$$P_{jk}^{a,b+1} = P_{jk}^{a,b} \exp \left[-\chi_P \left(\log P_{jk}^{a,b} - \log \tilde{P}_{jk}^{a,b} \right) \right]$$

where χ_P is a positive constant.

iii. Given wages and prices, we compute country-sector gross spending X_{jk}^a .

(a) Compute wage bill in each country:

$$W_i^a = w_i^a N_i.$$

(b) Given prices, compute the terms $e_{ik,js}^a$, and E_{ik}^a used in (C.22):

$$\begin{aligned}
e_{ik,js}^a &\equiv \mathbb{I}_{i=j} \gamma_{ik} \kappa_{is}^{\tau,a} + \alpha_{iks} (1 - \alpha_{is}) \kappa_{ijs}^{Y,a} \\
E_{ik}^a &\equiv \gamma_{ik} (W_i^a + \phi_i \sum_{j \in \mathcal{I}} W_j^a) \\
\text{where } \kappa_{is}^{\tau,a} &\equiv \sum_{o \in \mathcal{I}} \sum_{h \in \mathcal{H}_s} \frac{t_{oih}^{\text{av}}}{1 + t_{oih}^{\text{av}}} \zeta_{oish}^a \\
\kappa_{ijs}^{Y,a} &\equiv \sum_{h \in \mathcal{H}_s} \frac{1}{1 + t_{oih}^{\text{av}}} \zeta_{ijsh}^a \\
\zeta_{ijsh}^a &\equiv \begin{cases} \frac{\theta_{ijsh}^H [p_{ijh}^a]^{1-\sigma}}{[P_{jsh}^{H,a}]^{1-\sigma}} \frac{\theta_{jsh}^H [P_{jsh}^{H,a}]^{1-\eta}}{[P_{js}^{H,a}]^{1-\eta}} \frac{\theta_{js}^H [P_{js}^{H,a}]^{1-\kappa}}{[P_{js}^a]^{1-\kappa}} & \text{if } i = j \\ \frac{\theta_{ijsh}^F [p_{ijh}^a]^{1-\sigma}}{[P_{jsh}^{F,a}]^{1-\sigma}} \frac{\theta_{jsh}^F [P_{jsh}^{F,a}]^{1-\eta}}{[P_{js}^{F,a}]^{1-\eta}} \frac{\theta_{js}^F [P_{js}^{F,a}]^{1-\kappa}}{[P_{js}^a]^{1-\kappa}} & \text{if } i \neq j \end{cases}
\end{aligned}$$

(c) Applying (C.22), we obtain the vector of gross spending $X^a \equiv \{X_{js}^a\}$ as

$$X^a = (1 - e^a)^{-1} E^a.$$

iv. Use the labor demand equation and labor market clearing condition to update wages in the outer loop.

(a) Given country-sector spending, compute country-sector labor demand N_{is}^a by substituting (C.21) into (C.11):

$$N_{is}^a = \frac{1}{w_{is}^a} \alpha_{is} \sum_{j \in \mathcal{I}} \kappa_{ijs}^{Y,a} X_{js}^a$$

where X_{js}^a and $\kappa_{ijs}^{Y,a}$ were obtained in the previous step.

(b) If $\max_i |N_i - \sum_{s \in \mathcal{S}} N_{is}^a| < \text{tol}$, then stop. If not, then we set

$$\tilde{w}_i = w_i^a \exp \left[-\chi_w \left(\log N_i - \log \left(\sum_{k \in \mathcal{S}} N_{ik}^a \right) \right) \right]$$

where χ_w is a positive constant. Since we specify the world GDP to be the constant numeraire under the normalization in (C.23), we re-normalize wages such that

$$w_i^{a+1} = \frac{\sum_{j \in \mathcal{I}} N_j}{\sum_{j \in \mathcal{I}} \tilde{w}_j N_j} \tilde{w}_i,$$

which guarantees that $\sum_{i \in \mathcal{I}} w_i^{a+1} N_i = \sum_{i \in \mathcal{I}} N_i$.

C.4 Analytical Jacobian Matrices

We now turn to the analytical Jacobian of our model for changes in terms of trade and tariff revenue with respect to changes in imports of each good. We again use the convenient representation of the model in terms of ad-valorem equivalent import tariffs. Throughout this section, we use variables with hats to denote log-changes in that variable.

Prices. Log linearizing and vectorizing the system of equations for prices in (C.1)-(C.7), we obtain

$$\hat{p} = \mathcal{E}^{p,w} \hat{w} + \mathcal{E}^{p,1+t} (\widehat{1+t^{av}}) \quad (\text{C.36})$$

$$\text{where } \mathcal{E}^{p,w} = (I - \bar{\mathcal{E}}^{p,p^M} \bar{\mathcal{E}}^{p^M,p} \bar{\mathcal{E}}^{p,P} \bar{\mathcal{E}}^{P,P^G} \bar{\mathcal{E}}^{P^G,P_H^G} \bar{\mathcal{E}}^{P_H^G,p_H} \bar{\mathcal{E}}^{p_H,p})^{-1} \bar{\mathcal{E}}^{p,w}$$

$$\mathcal{E}^{p,1+t} = (I - \bar{\mathcal{E}}^{p,p^M} \bar{\mathcal{E}}^{p^M,p} \bar{\mathcal{E}}^{p,P} \bar{\mathcal{E}}^{P,P^G} \bar{\mathcal{E}}^{P^G,P_H^G} \bar{\mathcal{E}}^{P_H^G,p_H} \bar{\mathcal{E}}^{p_H,p})^{-1} \bar{\mathcal{E}}^{p,p^M} \bar{\mathcal{E}}^{p^M,p} \bar{\mathcal{E}}^{p,P} \bar{\mathcal{E}}^{P,P^G} \bar{\mathcal{E}}^{P^G,P_H^G} \bar{\mathcal{E}}^{P_H^G,p_H} \bar{\mathcal{E}}^{p_H,1+t}$$

$$\hat{p}_H = \mathcal{E}^{p_H,w} \hat{w} + \mathcal{E}^{p_H,1+t} (\widehat{1+t^{av}}) \quad (\text{C.37})$$

$$\text{where } \mathcal{E}^{p_H,w} = \bar{\mathcal{E}}^{p_H,p} \mathcal{E}^{p,w}$$

$$\mathcal{E}^{p_H,1+t} = \bar{\mathcal{E}}^{p_H,p} \mathcal{E}^{p,1+t} + \bar{\mathcal{E}}^{p_H,1+t}$$

$$\hat{p}_H^G = \mathcal{E}^{p_H^G,w} \hat{w} + \mathcal{E}^{p_H^G,1+t} (\widehat{1+t^{av}}) \quad (\text{C.38})$$

$$\text{where } \mathcal{E}^{p_H^G,w} = \bar{\mathcal{E}}^{p_H^G,p_H} \mathcal{E}^{p_H,w}$$

$$\mathcal{E}^{p_H^G,1+t} = \bar{\mathcal{E}}^{p_H^G,p_H} \mathcal{E}^{p_H,1+t}$$

$$\hat{p}^G = \mathcal{E}^{p^G,w} \hat{w} + \mathcal{E}^{p^G,1+t} (\widehat{1+t^{av}}) \quad (\text{C.39})$$

$$\text{where } \mathcal{E}^{p^G,w} = \bar{\mathcal{E}}^{p^G,p_H^G} \mathcal{E}^{p_H^G,w}$$

$$\mathcal{E}^{p^G,1+t} = \bar{\mathcal{E}}^{p^G,p_H^G} \mathcal{E}^{p_H^G,1+t}$$

$$\hat{P} = \mathcal{E}^{P,w} \hat{w} + \mathcal{E}^{P,1+t} (\widehat{1+t^{av}}) \quad (\text{C.40})$$

$$\text{where } \mathcal{E}^{P,w} = \bar{\mathcal{E}}^{P,P^G} \mathcal{E}^{p^G,w}$$

$$\mathcal{E}^{P,1+t} = \bar{\mathcal{E}}^{P,P^G} \mathcal{E}^{p^G,1+t}$$

$$\hat{p}^M = \mathcal{E}^{p^M,w} \hat{w} + \mathcal{E}^{p^M,1+t} (\widehat{1+t^{av}}) \quad (\text{C.41})$$

$$\text{where } \mathcal{E}^{p^M,w} = \bar{\mathcal{E}}^{p^M,p} \mathcal{E}^{p,w}$$

$$\mathcal{E}^{p^M,1+t} = \bar{\mathcal{E}}^{p^M,p} \mathcal{E}^{p,1+t}$$

The elasticity matrices are defined as follows:

$$\begin{aligned}
[\bar{\mathcal{E}}^{p_H,p}]_{ijh,ok} &= \mathbb{I}[i = o, h \in \mathcal{H}_k] \\
[\bar{\mathcal{E}}^{p_H,1+t}]_{ijh,odv} &= \mathbb{I}[ijh = odv] \\
[\bar{\mathcal{E}}^{p,w}]_{is,jk} &= \mathbb{I}[is = jk]\alpha_{is} \\
[\bar{\mathcal{E}}^{p,p^M}]_{isjk} &= \mathbb{I}[is = jk](1 - \alpha_{is}) \\
[\bar{\mathcal{E}}^{p^M,P}]_{is,jk} &= \mathbb{I}[i = j]\alpha_{iks} \\
[\bar{\mathcal{E}}^{P,P^G}]_{ik,gjs} &= \mathbb{I}[ik = js]\theta_{ik}^g \\
[\bar{\mathcal{E}}^{P^G,P^G_H}]_{gik,g'jh} &= \mathbb{I}[i = j, g = g', h \in \mathcal{H}_k]\theta_{ikh}^g \\
[\bar{\mathcal{E}}^{P^G_H,p_H}]_{gih,odv} &= \mathbb{I}[i = d, o \in \mathcal{I}_i^g, h = v]\theta_{oik(h)h}^g
\end{aligned} \tag{C.42}$$

Given this characterization, the change in consumer price indices can be expressed as

$$\begin{aligned}
\hat{p}^C &= \mathcal{E}^{PC,w}\hat{w} + \mathcal{E}^{PC,1+t}(\widehat{1 + t^{av}}) \\
\text{where } \mathcal{E}^{PC,w} &= \bar{\mathcal{E}}^{PC,P}\mathcal{E}^{P,w} \\
\mathcal{E}^{PC,1+t} &= \bar{\mathcal{E}}^{PC,P}\mathcal{E}^{P,1+t} \\
[\bar{\mathcal{E}}^{PC,P}]_{j,ik} &= \mathbb{I}[i = j]\gamma_{jk}
\end{aligned}$$

Labor market clearing. We begin by characterizing changes in trade flows using ζ_{ijsh} in (C.20). Log-linearizing and then vectorizing implies

$$\begin{aligned}
\hat{\zeta} &= \mathcal{E}^{\zeta,w}\hat{w} + \mathcal{E}^{\zeta,1+t}(\widehat{1 + t^{av}}) \\
\text{where } \mathcal{E}^{\zeta,w} &= \bar{\mathcal{E}}^{\zeta,p_H}\mathcal{E}^{p_H,w} + \bar{\mathcal{E}}^{\zeta,P^G_H}\mathcal{E}^{P^G_H,w} + \bar{\mathcal{E}}^{\zeta,P^G}\mathcal{E}^{P^G,w} + \bar{\mathcal{E}}^{\zeta,P}\mathcal{E}^{P,w} \\
\mathcal{E}^{\zeta,1+t} &= \bar{\mathcal{E}}^{\zeta,p_H}\mathcal{E}^{p_H,1+t} + \bar{\mathcal{E}}^{\zeta,P^G_H}\mathcal{E}^{P^G_H,1+t} + \bar{\mathcal{E}}^{\zeta,P^G}\mathcal{E}^{P^G,1+t} + \bar{\mathcal{E}}^{\zeta,P}\mathcal{E}^{P,1+t}
\end{aligned} \tag{C.43}$$

and where

$$\begin{aligned}
[\bar{\mathcal{E}}^{\zeta, P_H}]_{ijh, odv} &= \mathbb{I}[ijh = odv](1 - \sigma) \\
[\bar{\mathcal{E}}^{\zeta, P_H^G}]_{ijh, gdv} &= \mathbb{I}[j = d, i \in \mathcal{I}_j^g, h = v](\sigma - \eta) \\
[\bar{\mathcal{E}}^{\zeta, P^G}]_{ijh, gdk} &= \mathbb{I}[j = d, i \in \mathcal{I}_j^g, h \in \mathcal{H}_k](\eta - \kappa) \\
[\bar{\mathcal{E}}^{\zeta, P}]_{ijh, dk} &= -\mathbb{I}[j = d, h \in \mathcal{H}_k](1 - \kappa)
\end{aligned} \tag{C.44}$$

We next expand the labor market clearing condition in (C.18), combining it with a normalization that fixes nominal world GDP. Log-linearizing and vectorizing implies

$$\hat{w} = \mathcal{E}^{w, X} \hat{X} + \mathcal{E}^{w, 1+t} (\widehat{1 + t^{av}}) \tag{C.45}$$

$$\begin{aligned}
\text{where } \mathcal{E}^{w, X} &= \left(I - \bar{\mathcal{E}}^{w, W} \bar{\mathcal{E}}^{W, \zeta} \mathcal{E}^{\zeta, w} \right)^{-1} \bar{\mathcal{E}}^{w, W} \bar{\mathcal{E}}^{W, X} \\
\mathcal{E}^{w, 1+t^{av}} &= \left(I - \bar{\mathcal{E}}^{w, W} \bar{\mathcal{E}}^{W, \zeta} \mathcal{E}^{\zeta, w} \right)^{-1} \bar{\mathcal{E}}^{w, W} \left(\bar{\mathcal{E}}^{W, 1+t^{av}} + \bar{\mathcal{E}}^{W, \zeta} \mathcal{E}^{\zeta, 1+t} \right)
\end{aligned}$$

and where

$$\begin{aligned}
[\bar{\mathcal{E}}^{w, W}]_{i, j} &= \mathbb{I}[i = j] - \frac{N_j}{\sum_{o \in \mathcal{I}} N_o} \\
[\bar{\mathcal{E}}^{W, \zeta}]_{i, odh} &= \mathbb{I}[i = o] \frac{\alpha_{is(h)} X_{idh} / (1 + t_{idh}^{av})}{N_i} \\
[\bar{\mathcal{E}}^{W, X}]_{i, js} &= \frac{\alpha_{is}}{N_i} \sum_{h \in \mathcal{H}_s} \frac{X_{ijh}}{1 + t_{ijh}^{av}} \\
[\bar{\mathcal{E}}^{W, 1+t}]_{i, odh} &= -\mathbb{I}[i = o] \frac{\alpha_{is(h)} X_{idh} / (1 + t_{idh}^{av})}{N_i}
\end{aligned}$$

Goods market clearing. We finally turn to the goods market clearing condition,

$$X_{ik} = \gamma_{ik} F_i + \sum_{s \in \mathcal{S}} \alpha_{iks} (1 - \alpha_{is}) Y_{is}$$

We begin by characterizing final demand in (C.13)-(C.15). We obtain

$$\begin{aligned}
\hat{F} &= \mathcal{E}^{F, w} \hat{w} + \bar{\mathcal{E}}^{F, X} \hat{X} + \mathcal{E}^{F, 1+t} (\widehat{1 + t^{av}}) \\
\text{where } \mathcal{E}^{F, w} &= \bar{\mathcal{E}}^{F, w} + \bar{\mathcal{E}}^{F, \zeta} \mathcal{E}^{\zeta, w} \\
\mathcal{E}^{F, 1+t} &= \bar{\mathcal{E}}^{F, 1+t} + \bar{\mathcal{E}}^{F, \zeta} \mathcal{E}^{\zeta, 1+t}
\end{aligned} \tag{C.46}$$

and where

$$\begin{aligned} [\bar{\mathcal{E}}^{F,w}]_{j,i} &= \mathbb{I}[i = j] \frac{N_j}{F_j} \\ [\bar{\mathcal{E}}^{F,X}]_{j,ik} &= \mathbb{I}[i = j] \sum_{o \in \mathcal{I}} \sum_{h \in \mathcal{H}_k} \frac{t_{ojh}^{\text{av}} X_{ojh}}{F_j} \\ [\bar{\mathcal{E}}^{F,\zeta}]_{j,odh} &= \mathbb{I}[d = j] \frac{t_{ojh}^{\text{av}} X_{ojh}}{F_j} \\ [\bar{\mathcal{E}}^{F,1+t}]_{j,odh} &= \mathbb{I}[d = j] \frac{X_{ojh} / (1 + t_{ojh}^{\text{av}})}{F_j} \end{aligned}$$

Next, we characterize gross output. From (C.17), we obtain

$$\hat{Y} = \mathcal{E}^{Y,w} \hat{w} + \bar{\mathcal{E}}^{Y,X} \hat{X} + \mathcal{E}^{Y,1+t} (\widehat{1 + t^{\text{av}}}) \quad (\text{C.47})$$

where $\mathcal{E}^{Y,w} = \bar{\mathcal{E}}^{Y,\zeta} \mathcal{E}^{\zeta,w}$

$$\mathcal{E}^{Y,1+t} = \bar{\mathcal{E}}^{Y,1+t} + \bar{\mathcal{E}}^{Y,\zeta} \mathcal{E}^{\zeta,1+t}$$

and where

$$\begin{aligned} [\bar{\mathcal{E}}^{Y,\zeta}]_{is,odh} &= \mathbb{I}[i = o, h \in \mathcal{H}_s] \frac{X_{idh} / (1 + t_{idh}^{\text{av}})}{Y_{is}} \\ [\bar{\mathcal{E}}^{Y,X}]_{is,jk} &= \mathbb{I}[s = k] \sum_{h \in \mathcal{H}_s} \frac{X_{ijh} / (1 + t_{ijh}^{\text{av}})}{Y_{is}} \\ [\bar{\mathcal{E}}^{Y,1+t}]_{is,odh} &= -\mathbb{I}[i = o, h \in \mathcal{H}_s] \frac{X_{idh} / (1 + t_{idh}^{\text{av}})}{Y_{is}} \end{aligned}$$

Combining these expressions with a log-linearization of the goods market clearing condition implies

$$\hat{X} = \mathcal{E}^{X,w} \hat{w} + \mathcal{E}^{X,1+t} (\widehat{1 + t^{\text{av}}}) \quad (\text{C.48})$$

where $\mathcal{E}^{X,w} = \left(I - \bar{\mathcal{E}}^{X,F} \bar{\mathcal{E}}^{F,X} - \bar{\mathcal{E}}^{X,Y} \bar{\mathcal{E}}^{Y,X} \right)^{-1} \left(\bar{\mathcal{E}}^{X,P} \mathcal{E}^{P,w} + \bar{\mathcal{E}}^{X,F} \mathcal{E}^{F,w} + \bar{\mathcal{E}}^{X,Y} \mathcal{E}^{Y,w} \right)$

$$\mathcal{E}^{X,1+t} = \left(I - \bar{\mathcal{E}}^{X,F} \bar{\mathcal{E}}^{F,X} - \bar{\mathcal{E}}^{X,Y} \bar{\mathcal{E}}^{Y,X} \right)^{-1} \left(\bar{\mathcal{E}}^{X,P} \mathcal{E}^{P,1+t^{\text{av}}} + \bar{\mathcal{E}}^{X,F} \mathcal{E}^{F,1+t} + \bar{\mathcal{E}}^{X,Y} \mathcal{E}^{Y,1+t} \right)$$

where

$$\begin{aligned} [\bar{\mathcal{E}}^{X,P}]_{ik,js} &= \mathbb{I}[ik = js] \\ [\bar{\mathcal{E}}^{X,F}]_{ik,j} &= \mathbb{I}[i = j] \frac{\gamma_{ik} F_i}{X_{ik}} \\ [\bar{\mathcal{E}}^{X,Y}]_{ik,js} &= \mathbb{I}[i = j] \frac{\alpha_{iks} (1 - \alpha_{is}) Y_{is}}{X_{ik}} \end{aligned}$$

Solving for changes in wages and expenditure. Above, we derived expressions for the changes in wages and expenditures in terms of change in expenditure and wages, respectively, as well as changes in tariffs:

$$\begin{aligned} \hat{w} &= \mathcal{E}^{w,X} \hat{X} + \mathcal{E}^{w,1+t} (\widehat{1 + t^{\text{av}}}) \\ \hat{X} &= \mathcal{E}^{X,w} \hat{w} + \mathcal{E}^{X,1+t} (\widehat{1 + t^{\text{av}}}). \end{aligned} \quad (\text{C.49})$$

Substituting and inverting, we solve for the change in wages:

$$\hat{w} = \left(I - \mathcal{E}^{w,X} \mathcal{E}^{X,w} \right)^{-1} \left(\mathcal{E}^{w,X} \mathcal{E}^{X,1+t} + \mathcal{E}^{w,1+t} \right) (\widehat{1 + t^{\text{av}}}). \quad (\text{C.50})$$

Changes in all other equilibrium variables can be obtained by substituting the change in wages—as well as the implied change in expenditures—into the various expressions above.

Changes in trade quantities. Recall that $X_{ijh} = \zeta_{ijs(h)h} X_{js(h)}$, $X_{ijh} = p_{ijh} m_{ijh}$, and $p_{ijh} = (1 + t_{ijh}^{\text{av}}) (\theta_{ijh})^{-1} p_{is(h)}$. Normalizing $\hat{m}_{ijh} = 0$ if $m_{ijh} = 0$, we have

$$\hat{m} = \bar{\mathcal{E}}^{m,\zeta} \hat{\zeta} + \bar{\mathcal{E}}^{m,X} \hat{X} + \bar{\mathcal{E}}^{m,p} \hat{p} + \bar{\mathcal{E}}^{m,1+t} (\widehat{1 + t^{\text{av}}}) \quad (\text{C.51})$$

where

$$\begin{aligned} [\bar{\mathcal{E}}^{m,\zeta}]_{ijh,odv} &= \mathbb{I}[m_{ijh} > 0] \mathbb{I}[ijh = odv] \\ [\bar{\mathcal{E}}^{m,X}]_{ijh,dk} &= \mathbb{I}[m_{ijh} > 0] \mathbb{I}[j = d, h \in \mathcal{H}_k] \\ [\bar{\mathcal{E}}^{m,p}]_{ijh,ok} &= -\mathbb{I}[m_{ijh} > 0] \mathbb{I}[i = o, h \in \mathcal{H}_k] \\ [\bar{\mathcal{E}}^{m,1+t}]_{ijh,odv} &= -\mathbb{I}[m_{ijh} > 0] \mathbb{I}[ijh = odv] \end{aligned}$$

Change in terms of trade. Consider the terms-of-trade effect on each country:

$$dToT_i = \sum_{d \in \mathcal{I}, h \in \mathcal{H}} dp_{idh}^w m_{idh} - \sum_{o \in \mathcal{I}, h \in \mathcal{H}} dp_{oih}^w m_{oih}$$

Since $p_{ijh}^w = p_{ijh} / (1 + t_{ijh}^{av}) = (\theta_{ijh})^{-1} p_{is}$, we have

$$dToT = \bar{\mathcal{E}}^{ToT, p} \hat{p} \quad (\text{C.52})$$

$$\text{where } [\bar{\mathcal{E}}^{ToT, p}]_{i, js} = \mathbb{I}[i = j] \left(\sum_{d \in \mathcal{I}, h \in \mathcal{H}_s} \frac{X_{idh}}{1 + t_{idh}^{av}} \right) - \left(\sum_{h \in \mathcal{H}_s} \frac{X_{jih}}{1 + t_{jih}^{av}} \right)$$

Fiscal externalities. Consider the fiscal externality on each country:

$$dR_i = \sum_{o \in \mathcal{I}, h \in \mathcal{H}} t_{oih} dm_{oih}$$

Vectorizing, we have

$$dR = \bar{\mathcal{E}}^{R, m} \hat{m} \quad (\text{C.53})$$

$$\text{where } [\bar{\mathcal{E}}^{R, m}]_{i, odh} = \mathbb{I}[i = d] t_{oih}^{av} \frac{X_{oih}}{1 + t_{oih}^{av}}$$

From Tariff to Import Changes. The last step of our derivation is to convert the Jacobian matrices above—which are derivatives with respect to tariff changes—into the Jacobian matrices that enter our estimating equation—which are derivatives with respect to import changes. We do so by multiplying each original Jacobian matrix by the inverse of the Jacobian matrix of imports with respect to tariffs:

$$\frac{dToT}{d \log m} = \frac{dToT}{d \log(1 + t)} \left[\frac{d \log m}{d \log(1 + t)} \right]^{-1},$$

$$\frac{dR}{d \log m} = \frac{dR}{d \log(1 + t)} \left[\frac{d \log m}{d \log(1 + t)} \right]^{-1}.$$