Why is Trade Not Free? A Revealed Preference Approach*

Rodrigo Adão
Chicago Booth

Arnaud Costinot
MIT

Dave Donaldson
MIT

John Sturm
Princeton

Abstract

A prominent class of political economy-based explanations argues that trade protection is used as a form of redistribution. We develop a methodology that can be used to reveal the welfare weights that a nation's import tariffs implicitly place on different groups of society. Our analysis builds on a general tariff formula that expresses constrained Pareto-efficient trade taxes as a function of these weights and a few other sufficient statistics. Our formula can accommodate both redistributive and non-redistributive motives for trade protection as well as the existence of non-tariff barriers and international trade agreements. The key inputs required to identify welfare weights from tariffs using our formula are the changes in real earnings associated with the changes in imports of various goods. We measure those earnings changes for the United States in 2017 using a quantitative trade model whose predictions we validate against the observed earnings changes caused by Trump's trade war. Our empirical analysis reveals that the redistributive motive accounts for a large fraction of US tariff variation, mostly driven by significant differences in welfare weights across US households employed in different sectors. Perhaps surprisingly, differences in welfare weights across US states are found to play a much smaller role.

*This version: June 2023. Author contacts: rodrigo.adao@chicagobooth.edu, costinot@mit.edu, ddonald@mit.edu, and sturmjohna@gmail.com. We are grateful to Shotaro Beppu, Robin Li, Noah Siderhurst and Akash Thakkar for outstanding research assistance, to Paola Conconi, Pablo Fajgelbaum, Penny Goldberg, Giovanni Maggi, Bob Staiger, Jon Vogel and seminar audience members for helpful comments, and to Aksel Erbahar for generous help with data.

1 Introduction

After decades of retreat, recent years have been marked by a return to protectionism—from President Trump's 2018 increase in US tariffs to the 2020 UK exit from the European Union. This new reality brings heightened importance to one of the most classical questions in international economics: Why is trade not free?

This question is the *raison de vivre* of the literature on the political economy of trade policy reviewed in Rodrik (1995), Gawande and Krishna (2003), and McLaren (2016). Empirical evidence accumulated around the question can be broadly organized into two main periods, with the influential work of Grossman and Helpman (1994) as a turning point. Before Grossman and Helpman (1994), most empirical findings derived from "kitchen-sink" regressions with trade policy on the left-hand side and various political variables on the right-hand side, with Rodrik (1995) criticizing the gulf between theoretical and empirical work in this area. After Grossman and Helpman (1994), empirical work became structural and centered around the equation linking optimal trade taxes to political and economic variables in their elegant "protection for sale" model, with Goldberg and Maggi (1999) an early and influential example of research in this area.

The key equation in Grossman and Helpman (1994) that inspired a generation of empirical work on the determinants of protection states that the (specific) trade tax t_n charged by the "Home" government on any good n satisfies

$$t_n = \left(\frac{I_n - \alpha_L}{a + \alpha_L}\right)\left(\frac{Z_n}{e_n}\right). \tag{1}$$

In this expression, I_n indicates whether the producers of good n are organized (to lobby the Home government) or not; α_L measures the share of Home's population in such organized groups; a corresponds to the weight that the Home government places on aggregate Home social welfare (as opposed to lobbyists' campaign contributions); Z_n is the ratio of output to the value of imports for good n; and e_n is the price elasticity of Home's import demand for good n.

Despite the impact that equation (1) has had on research in the field, twenty years later McLaren (2016) has lamented how, "In World War I thousands of lives would be spilled over a few feet of land, and in this literature thousands of pages are written to examine and debate a single equation."[1] Our starting point in this paper is therefore to derive a new and less restrictive tariff formula that relies only on the assumption that

[1] A non-exhaustive list of empirical papers testing the predictions of Grossman and Helpman (1994) and various extensions of the original "protection for sale" model includes Gawande and Bandyopadhyay (2000), Mitra et al. (2002), Matschke and Sherlund (2006), Bombardini (2008), and Gawande et al. (2009).

trade taxes are set via some political process that is (constrained) Pareto efficient, a mild requirement satisfied by many political-economy models in the existing literature. It is otherwise general in that it does not require any restriction on preferences, technology, market structure nor the specifics of how trade policy is determined.

Our general tariff formula states that Pareto efficient trade taxes satisfy

$$t_n = -\sum_h \beta(h) \times \frac{\partial[\omega(h) - \bar{\omega}]}{\partial m_n} + \text{residual}_n. \tag{2}$$

Here, we consider an arbitrary set of households h, and the derivative $\partial[\omega(h) - \bar{\omega}]/\partial m_n$ denotes the marginal change in the real earnings of household h, relative to the average earnings changes in the population, associated with a marginal increase in the imports m_n of good n, holding constant imports of all other goods taxed by the government. The term $\beta(h)$ denotes the social marginal return of a transfer to household h that Home's trade policymaking process arrives at, whatever is the underlying process that causes it to "choose" this particular point on the economy's Pareto frontier. Finally, the structural residual_n captures the effects of non-redistributive motives for protection, namely terms-of-trade manipulation and second-best corrections for distortions, which we also fully characterize.

Since the "protection for sale" model of Grossman and Helpman (1994) features Pareto efficient lobbying, equation (1) is a special case of (2). In particular, the term $(I_n - \alpha_L)/(a + \alpha_L)$ describes two possible values for the welfare weights $\beta(h)$, depending on whether sector n is organized or not and whether household h owns inputs specific to that sector. The term Z_n/e_n measures the sensitivity of real earnings to imports $\partial[\omega(h) - \bar{\omega}]/\partial m_n$ in their partial equilibrium model, whereas the structural residual_n is zero, since the economy is small and undistorted.[2]

Building on our general tariff formula (2), we develop a methodology that allows researchers to use a society's observed trade policy in order to reveal the unknown welfare weights that the society has chosen, whether explicitly or implicitly. The basic idea is to treat (2) as a regression equation in which the dependent variable is the trade tax t_n, the regressors are $\{\partial[\omega(h) - \bar{\omega}]\}/\partial m_n$, and the coefficients of interest are the vector of welfare weights $\{\beta(h)\}$. Intuitively, our approach attributes a higher welfare weight to households for which we observe higher tariffs in the goods whose imports have a stronger negative impact on their real income (relative to the average household).

[2] Grossman and Helpman (1995) extends their "protection for sale" formula to the case of large economies whose tariffs may also affect their terms-of-trade. This is another special case of our general formula.

Importantly, because the estimated welfare weights are valid regardless of the underlying political process that gives rise to them, this method highlights a natural division of labor in the study of how distributional forces can lead to protectionism. First, we can draw on the vast body of recent work that has advanced progress on the economic model of how trade (and hence trade policy) affects earnings and prices in order to construct measures of $\{\partial[\omega(h) - \bar{\omega}]/\partial m_n\}$. And second, given the estimated welfare weights, we can go on to ask: How important is the redistributive motive for trade policy relative to other motives? As well as: How do welfare weights compare to those predicted by various political economy models? Competing views about trade policy—for example that it favors special interest groups formed along regional, sectoral, economic class, political party, or identity—all boil down to competing statements about relative welfare weights. This two-step approach to the study of the political economy of trade recognizes—in contrast to the older kitchen-sink regressions—a key insight from the Grossman and Helpman (1994) equation: that the determinants of observed trade taxes include both political considerations, as reflected in the welfare weights $\{\beta(h)\}$, and economic considerations, as reflected in the sensitivity of earnings to imports $\{\partial[\omega(h) - \bar{\omega}]/\partial m_n\}$. Thus, to go from observed trade policy to inferences about a given government's preferences over different constituents of society, one must first account for these economic considerations.

For our baseline analysis, we apply our general formula to study the redistributive motive embedded in the trade policy of the United States in 2017—that is, before the changes introduced in 2018 by the Trump administration. To measure $\partial[\omega(h) - \bar{\omega}]/\partial m_n$, we develop a quantitative model of the US economy that features heterogeneous exposure to international trade across US regions and sectors, both directly via exports and importsand indirectly via input-output and domestic trade linkages. We use estimates of the model's structural parameters that were obtained by Fajgelbaum et al. (2020) from the variation induced by the 2018 tariff change, and calibrate the model to match available data on trade and production across sectors and states in 2017. This economic model therefore yields estimates of $\{\partial[\omega(h) - \bar{\omega}]/\partial m_n\}$ for all US households based on their region and sector of employment, and for thousands of country-product varieties n. We use the testing procedure of Adao et al. (2023a) to validate these model-implied estimates and verify that, reassuringly, they are consistent with the differential response of earnings across US regions and sectors to the tariff changes observed during the Trump's trade war.

Armed with the previous estimates, we turn to the estimation of the welfare weights using equation (2). The key assumption in our implementation is that conditional on a vector of controls, our measures of the economic return from imports $\{\partial[\omega(h) - \bar{\omega}]/\partial m_n\}$ are orthogonal to the other considerations for trade protection embedded in residual_n

across all varieties n. Our estimates reveal a number of novel findings about US welfare weights. First, the redistributional motive accounts for a significant share of the cross-sectional variation in US tariffs: 30% in 2017. Second, we find a large disparity in welfare weights across sectors; for example, households from the sector in the 90th percentile enjoy about 1.4 units greater social marginal utility of income (when normalized such that the weighted average across all US households is one) than that at the 10th percentile. In contrast, differences across households from different regions are much more muted, with those from the state at the 90th percentile enjoying only 0.06 units higher social marginal utility of income than that at the 10th percentile. The much higher dispersion in the social welfare weights across sectors than states implies that the redistribution motive embedded in the US tariff schedule that we estimate is almost entirely explained by redistribution across sectors.

Our final exercise evaluates the economic implications of removing the redistributive motive from US trade policy in 2017. To do so, we simulate the change in real earnings of all households that would occur if tariffs were to be purged of their redistributive component, as would happen if, for example, redistributive objectives could be fulfilled via other instruments. Such a change would see the 90th percentile sector-region enjoy a rise in its real income of $2,185 (per worker per annum), and the 10th percentile sector-region suffer a drop of $7,275. These effects give a sense of the magnitude of the as-if transfers that 2017 US tariffs engineer across households.

Related Literature

This paper combines central ideas from the public finance and international trade literature to develop a new way of identifying the determinants of trade policy.

From a theoretical standpoint, our general tariff formula builds on the type of necessary first-order condition that is common in the public finance literature on optimal commodity taxation, e.g. Diamond and Mirrlees (1971) and Greenwald and Stiglitz (1986). Such tax formulas typically involve a system of simultaneous equations. In contrast, we provide direct expressions for the optimal tariffs, as in Costinot and Werning (2018), where the determinants of the optimal tariff on each good are given by the marginal impact of its imports. One can think of this approach as providing a Pigouvian perspective on the determinants of trade protection. Pigouvian taxation calls for taxes on any economic activity whose effect on social welfare is not internalized by those directly involved in that activity. We apply this general principle to importing and exporting activities.

An attractive feature of our general tariff formula is that it can readily accommodate a number of dimensions relevant for the determinants of trade protection in practice. First, it remains unchanged in the presence of non-tariff barriers like product standards (e.g. Bagwell and Staiger, 2001, Grossman et al., 2021, or Maggi and Ossa, forthcoming). Second, it readily extends to environments where trade taxes may not vary across goods from different origin countries, because of a most favored nation (MFN) clause or where tariffs may have arisen through trade negotiations, provided that such trade negotiations have led to a global Pareto optimum (as in Bagwell and Staiger, 1999). This is important since this implies that for the purposes of studying the redistributive motive for trade protection, one may also use negotiated tariffs.[3] Third, our formula can easily incorporate various distortions from imperfect competition (as in Helpman and Krugman, 1989) to externalities due to pollution (as in Kortum and Weisbach, 2021) or psychosocial costs (as in Grossman and Helpman, 2021).

From the public finance literature, we also borrow the general idea of using observed taxes to infer social preferences, as in, for instance, Werning (2007), Bourguignon and Spadaro (2012), and Jacobs et al. (2017).[4] Rather than committing to a specific model of the political process, e.g. direct democracy (Mayer, 1984), political support function (Hillman, 1982), tariff formation function (Findlay and Wellisz, 1982), electoral competition (Magee et al., 1989), and influence-driven contributions (Grossman and Helpman, 1994), that would each generate different welfare weights, $\beta(h)$, we propose to estimate such weights directly by asking: given the redistributive impact of import restrictions in particular sectors, $\{\partial[\omega(h) - \bar{\omega}]/\partial m_n\}$, which sectors tend to receive a higher tariff, t_n? Assuming that redistributive motives are orthogonal to other motives, at least after controlling for a subset of them, the slope of a regression of the latter on the former identifies welfare weights.[5]

From an empirical standpoint, a striking feature of empirical work concerning the political economy of trade policy—as reviewed in Rodrik (1995), Gawande and Krishna (2003), and McLaren (2016)—is the limited extent to which it draws on advances in trade modeling and empirical estimation of causal responses of labor market outcomes to trade policy (e.g. Attanasio et al., 2004, Topalova, 2010, McCaig, 2011, and Kovak, 2013). This

[3]Of course, whether tariffs are negotiated or not matters for the impact of terms-of-trade considerations, as documented empirically by Broda et al. (2008). The extension of our formula to the case of trade talks shows that the distinction boils down to the welfare weight given to foreigners, which affects the value of the coefficient in front of terms-of-trade considerations.

[4]Our analysis also relates to that of Fajgelbaum et al. (2023), which uses proposals for California's High-Speed Rail system to infer policymakers' preferences for location-based redistribution.

[5]In abstracting from the details of the political process and focusing on the associated welfare weights, our analysis also relates to Baldwin (1987) who stresses the equivalence between tariffs chosen by lobbying-influenced policy makers and those maximizing a social welfare function with extra weights on profits.

means that, despite the fact that the existence of heterogeneous causal impacts of changes in imports on earnings is the primary rationale for trade protection in the political-economy literature, modern knowledge of such impacts are not actually used when attempting to infer the reasons for protectionism. By contrast, we give center stage to this response by drawing on a rich quantitative model of heterogenous participation in trade across sectoral and geographical groups within the same country, which we validate empirically using the estimated causal response of US labor markets to Trump's trade war.[6]

2 A General Tariff Formula

The goal of this section is to derive the structure of Pareto efficient trade taxes. We do so via a general tariff formula that features three generic motives for trade policy: (*i*) redistribution, which will be the main focus of our empirical analysis; (*ii*) terms-of-trade manipulation, which will be controlled for in our regressions; and (*iii*) distortions, which will be treated as a structural residual.

2.1 Environment

We focus on a single country, Home, that can trade with the rest of the world subject to its preferred trade taxes. Home comprises many firms $f \in \mathcal{F}$ and households $h \in \mathcal{H}$. Firms and households can produce and consume goods $n \in \mathcal{N}$. Goods encompass final goods, intermediate inputs, as well as labor and other primary factors. Both production and consumption may be subject to externalities $z \equiv \{z_k\}$ to be described further below.

Domestic Technology. Firm f's technology is described by a production set $\Upsilon(z; f)$. A production plan consists of a net output vector $y(f) \equiv \{y_n(f)\}$. It is feasible if

$$y(f) \in \Upsilon(z; f).$$

Domestic Preferences. A consumption plan for household h consists of a vector of goods demanded $c(h) \equiv \{c_n(h)\}$. Consumption plans must lie in a feasible set $\Gamma(z; h)$. A

[6] In contrast to the original partial equilibrium model of Grossman and Helpman (1994), our quantitative model allows the sensitivity of real earnings to be shaped by domestic input-output linkages and other general-equilibrium considerations, such as adjustments in the relative price of local non-tradables, in line with the recent quantitative models reviewed in Caliendo and Parro (2022). See also Ossa (2011), Ossa (2014), and Ossa (2016) for earlier quantitative analysis of the welfare consequences of commercial policy.

feasible consumption plan $c(h) \in \Gamma(z;h)$ delivers utility

$$u(c(h), z; h).$$

Prices, Taxes, and Transfers. International transactions are subject to specific trade taxes $t \equiv \{t_n\} \in \mathcal{T}$. Trade taxes create a wedge between the prices $p \equiv \{p_n\}$ faced by domestic firms and households and the prices $p^w \equiv \{p_n^w\}$ in the rest of the world. For any good n that is traded between Home and the rest of the world,

$$p_n = p_n^w + t_n. \tag{3}$$

If a good n is imported, $t_n \geq 0$ corresponds to an import tariff, while $t_n \leq 0$ corresponds to an import subsidy. If good n is exported, $t_n \geq 0$ corresponds to an export subsidy, while $t_n \leq 0$ corresponds to an export tax. Trade taxes on a given good are either unrestricted, $t_n \in \mathbb{R}$, or restricted to be zero, $t_n \in \{0\}$. For instance, Home's government may be unable to tax imports of services, for technological reasons, or prohibited from imposing export taxes, for constitutional reasons. We let $\mathcal{N}^T$ denote the set of goods that can be taxed.[7] Tax revenues are rebated to domestic households through a uniform lump-sum transfer τ.

Foreign Offer Curve. We summarize trade with the rest of the world by an offer curve $\Omega(p^w, z)$. For given foreign prices p^w, it describes the vector of Home's net imports $m \equiv \{m_n\}$ that the rest of the world is willing to export. A vector of net imports is feasible if

$$m \in \Omega(p^w, z). \tag{4}$$

Externalities. For a given domestic allocation $\{y(f), c(h)\}$, a vector of net imports m, and a vector of domestic and foreign prices (p, p^w), the vector of externalities satisfies

$$z \in \mathcal{Z}(\{y(f), c(h)\}, m, p, p^w). \tag{5}$$

This accommodates financial frictions that affect households' consumption sets $\Gamma(z;h)$, knowledge spillovers that affect firms' production sets $Y(z;f)$, carbon emissions that may affect both firms' technologies and households' utilities $u(c(h), z; h)$, as well as psychosocial costs that may only affect the latter, as in recent models of identity politics.

[7] Although the choice of numeraire never appears explicitly in our analysis, the numeraire good, whose trade tax can be normalized to zero, is always implicitly excluded from $\mathcal{N}^T$. This convention explains why indeterminacy of trade taxes due to Lerner symmetry plays no role in Proposition 1 below.

2.2 Competitive Equilibrium

Profit maximization. Each firm f chooses its vector of net output $y(f)$ to solve

$$\max_{y \in Y(z;f)} p \cdot y, \tag{6}$$

where the dot product $\cdot$ refers to the inner product, $p \cdot y = \sum_n p_n y_n$. We let $\pi(p, z; f)$ denote the value function associated with (6), i.e. the profits of firm f, expressed as a function of the domestic prices p and the externalities z.

Utility maximization. Each household h chooses its vector of consumption $c(h)$ to solve

$$\begin{aligned} &\max_{c \in \Gamma(z;h)} u(c, z; h) \\ &\text{subject to: } p \cdot c = \pi \cdot \theta(h) + \tau, \end{aligned} \tag{7}$$

where $\pi \equiv \{\pi(p, z; f)\}$ is the vector of firms' profits and $\theta(h) \equiv \{\theta(f, h)\}$ is the vector of firms' shares held by household h. Endowments of goods or factors by household h correspond to it fully owning simple firms with production sets given by a singleton, as will be the case in the next section. Below we let $y(h) \equiv \{\sum_{f \in \mathcal{F}} y_n(f)\theta(f, h)\}$ denote the vector of output associated with household h, $\mu(h)$ denote the Lagrange multiplier associated with its budget constraint, and $e(p, z, u; h) \equiv \min_{c \in \Gamma(z;h)}\{p \cdot c | u(c, z; h) \geq u\}$ denote its expenditure function.

Market clearing and government's budget balance. Total demand by domestic households equals total supply by domestic firms and total exports from the rest of the world,

$$\sum_{h \in \mathcal{H}} c(h) = \sum_{f \in \mathcal{F}} y(f) + m. \tag{8}$$

Finally, the budget constraint of the domestic government is

$$t \cdot m = H\tau, \tag{9}$$

where H is the total number of households at Home.

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

Definition 1. *A competitive equilibrium with trade taxes $t \in \mathcal{T}$ is a vector of domestic and foreign prices (p, p^w), a vector of net imports m, a vector of externalities z, a domestic allocation*

$\{y(f), c(h)\}$, and a transfer τ such that: (i) (p, p^w) satisfy (3); (ii) m satisfies (4); (iii) z satisfies (5); (iv) $y(f)$ solves (6) for all $f \in \mathcal{F}$; (v) $c(h)$ solves (7) for all $h \in \mathcal{H}$; (vi) all markets clear, as described in (8); and (vii) the government's budget is balanced, as described in (9).

2.3 Pareto-Efficient Trade Taxes

It is standard in the literature on the political economy of trade policy to model explicitly various features of the political process, from the nature of electoral competition to the possibility of lobbying. We propose instead to remain agnostic about these considerations and only require that trade taxes be (constrained) Pareto-efficient.

Definition 2. *A vector of trade taxes t^* is Pareto-efficient if there exists a household h_0 and a vector of utility $\{\underline{u}(h)\}_{h \neq h_0}$ such that t^* solves*

$$\max_{t \in \mathcal{T}} u(c(h_0), z; h_0)$$
$$\text{subject to: } u(c(h), z; h) \geq \underline{u}(h) \text{ for } h \neq h_0,$$
$$(\{c(h)\}, z) \in \mathcal{E}(t),$$

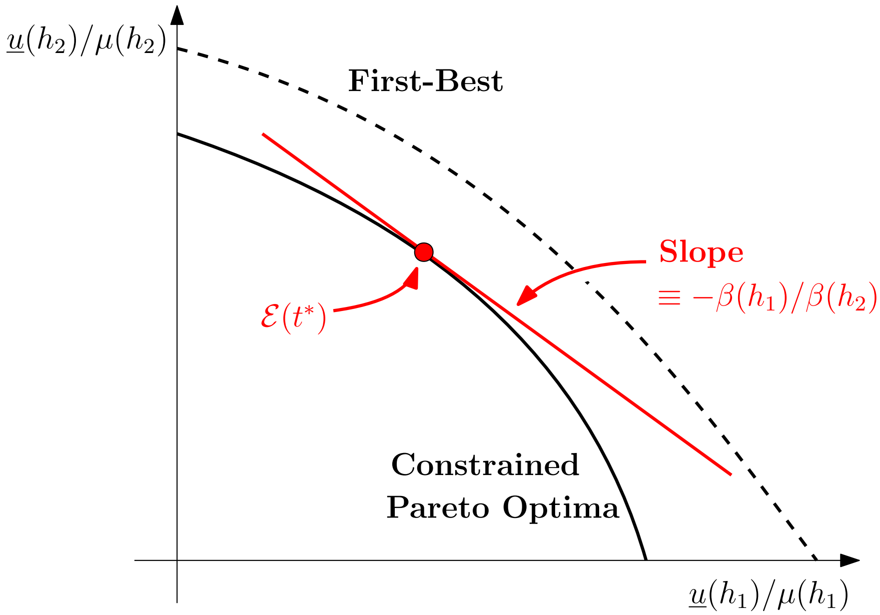
where $\mathcal{E}(t)$ denotes the set of domestic consumption and externality vectors attainable in a competitive equilibrium with trade taxes t.

In our analysis, the different utility levels $\{\underline{u}(h)\}$ implicitly reveal the relative importance of various political forces, such as voters from some US states being more likely to be pivotal in presidential elections or firms from some industries being more likely to lobby. We let $\nu(h)$ denote the Lagrange multiplier associated with the utility constraint of household h, with the convention $\nu(h_0) = 1$. Hence the social marginal utility of h's income is $\lambda(h) \equiv \mu(h)\nu(h)$, the average social marginal utility of income is $\bar{\lambda} \equiv \sum_h \lambda(h)/H$, and the social marginal return of a hypothetical lump-sum transfer to household h is $\beta(h) \equiv \lambda(h)/\bar{\lambda}$. Figure 1 illustrates how the choice of Pareto-efficient trade taxes $t^* \in \mathcal{T}$ implictly reveals those social marginal returns.

To characterize Pareto efficient trade taxes, it is convenient to apply a change of variables. Rather than treat a given equilibrium variable x as a function $\tilde{x}(t)$ of the vector of trade taxes $t \in \mathcal{T}$, we propose to treat it as a function $x(m^T)$ of the vector of taxable imports $m^T \equiv \{m_n\}_{n \in \mathcal{N}_T}$. For each variable x, this is formally equivalent to defining $x(m^T) \equiv \tilde{x}(t^{-1}(m^T))$, with $t^{-1}(m^T)$ the vector t that solves: $\tilde{m}_n(t) = m_n$ for all $n \in \mathcal{N}^T$.[8]

[8]Throughout we assume that, local to the observed equilibrium, the solution to this system exists and is unique. We view this as a mild requirement that rules out extreme environments, such as those where

Figure 1: Pareto-Efficient Trade Taxes



Notes: This figure plots the constrained Pareto frontier (solid line) between two households h_1 and h_2 that obtains as one varies the trade taxes $t \in \mathcal{T}$ applied in a competitive equilibrium. The slope of the constrained Pareto frontier at the chosen trade taxes t^* reveals the ratio of social marginal returns $\beta(h_1)/\beta(h_2)$. The first-best frontier (dashed line) is the set of Pareto optima that would arise if only technological and resource constraints applied. Due to the presence of externalities, the two frontiers may not be tangent.

Under the previous notation, the vectors of partial derivates $\partial p/\partial m_n$, $\partial p^w/\partial m_n$, and $\partial z/\partial m_n$ then measure the changes in domestic prices, foreign prices, and externalities, respectively, associated with whatever change in trade taxes induces a marginal increase in the net imports of any given good $n \in \mathcal{N}^T$, holding fixed the imports of all other goods in $\mathcal{N}^T$.

Let $\partial \omega(h)/\partial m_n \equiv [y(h) - c(h)] \cdot (\partial p/\partial m_n)$ denote the change in household h's real income caused by the increase in net imports of good n via its impact on domestic prices p; let $\partial \bar{\omega}/\partial m_n \equiv \sum_h [\partial \omega(h)/\partial m_n]/H$ denote its average across the population; and let $\partial(\omega - \bar{\omega})/\partial m_n \equiv \{\partial(\omega(h) - \bar{\omega})/\partial m_n\}$ denote the vector of deviations from the average. Our main proposition shows how the previous statistic, together with the changes in foreign prices $\partial p^w/\partial m_n$ and externalities $\partial z/\partial m_n$, shape Pareto efficient trade taxes.

preferences over net imports are Leontief and so multiple vector of trade taxes t may be associated with the same import vector m^T. As already discussed in footnote 7, standard indeterminacies with respect to the overall level of trade taxes are implicitly dealt with the choice of the goods that can be taxed and must at least exclude one numeraire good.

Proposition 1. *Pareto efficient trade taxes satisfy*

$$t_n^* = \underbrace{-\beta \cdot \frac{\partial(\omega - \bar{\omega})}{\partial m_n}}_{\textit{redistribution}} + \underbrace{m \cdot \frac{\partial p^w}{\partial m_n}}_{\textit{terms-of-trade}} + \underbrace{\epsilon \cdot \frac{\partial z}{\partial m_n}}_{\textit{distortions}} \text{ for all } n \in \mathcal{N}^T, \tag{10}$$

where $\beta \equiv \{\beta(h)\}$ denotes the social marginal returns of transfers to different households; and $\epsilon \equiv \sum_{h\in\mathcal{H}} \beta(h)[e_z(h) - \pi_z(h)]$ denotes the social marginal cost of externalities, with $e_z(h) \equiv \{\partial e(p, z, u(h); h)/\partial z_k\}$ and $\pi_z(h) \equiv \{\sum_{f\in\mathcal{F}} \theta(f, h)\partial\pi(p, z; f)/\partial z_k\}$.

The formal proof can be found in Appendix A. The general tariff formula presented in equation (10) states that there are three broad reasons why Home's government may want to tax the net imports of a given good n.

First, restricting net imports may affect real incomes via changes in domestic prices. Thus, a government may engineer as-if transfers from households with low social marginal return (i.e. a low $\beta(h)$) towards households with high social marginal return (i.e. a high $\beta(h)$). This is the redistributional motive captured by the first term, $-\beta \cdot \partial(\omega - \bar{\omega})/\partial m_n$, which will be at the core of our empirical analysis. Note that the redistributional motive is zero if $\partial(\omega - \bar{\omega})/\partial m_n = 0$, which occurs if changes in imports do not differentially affect real earnings in the population, or if $\beta(h) = 1$ for all h, which occurs if households have identical quasi-homothetic preferences and Home's government is utilitarian, a standard benchmark in the trade literature.

Second, restricting net imports may lower Home's import prices and increase its export prices. This is the terms-of-trade motive captured by the second term, $m \cdot \partial p^w/\partial m_n$, which we will use as a control in our main specification. As usual, this second term is zero in the case of a small open economy that may manipulate domestic prices p, but not foreign prices p^w. Note that given our change of variables, the terms-of-trade motive takes a particularly simple form in equation (10). It is akin to the classical optimal tariff formula that obtains in a two-good environment—in which the optimal tariff is equal to the inverse of the elasticity of the foreign export supply curve—despite that the fact that we impose no restrictions on the number of goods (nor on preferences and technology).

Third, restricting net imports may reduce negative externalities or raise positive ones. This is the typical second-best motive for trade protection captured by the third term, $\epsilon \cdot \partial z/\partial m_n$. Again, due to our change of variables, this third motive can be expressed in an intuitive manner as the sum of the marginal change in distortionary activities caused by by one extra unit of import of good n, each multiplied by the social cost of that activity.

In a competitive equilibrium, households and firms do not internalize any of these three considerations. Following a general Pigouvian logic, the optimal trade tax on a given good n requires them to pay, at the margin, for the potential negative impact of that good's imports on social welfare, a perspective emphasized in Costinot and Werning (2018). This is true regardless of whether import restrictions may affect social welfare via distributional or efficiency considerations.

2.4 Extensions

Below we will use Proposition 1 to estimate the role played by the redistributional motive for trade protection. Before we do so, we discuss its robustness to a number of considerations from which we have abstracted. Formal proofs can be found in Appendix A.2.

Policy Instruments. While the economic environment considered in Section 2.1 is general along many dimensions, it restricts the policy instruments available to the domestic government to specific trade taxes. As is well-known, the restriction to specific rather than ad-valorem trade taxes is without loss of generality under perfect competition. The critical assumption is that the government can create a wedge between foreign prices p^w—which affect the decision of foreigners via (4)—and domestic prices p—which affect the decisions of domestic firms and households via (6) and (7). The specific or ad-valorem nature of the trade tax through which the wedge comes about is irrelevant.

In practice, a government may also choose to restrict trade flows via non-tariff barriers, such as product standards that domestic and foreign firms may have to satisfy in order to sell to domestic households. As we show in Appendix A.2, the existence of product standards does not affect Proposition 1. That is, the existence of standards may affect the particular values of the sufficient statistics entering equation (10), but not the fact that equation (10) must continue to hold.[9]

In addition, a government may also be unable to set all tariffs freely. Subsets of goods may have to be subject to the same trade tax—for instance, they may be prohibited from varying across goods from different origin countries, because of a most favored nation (MFN) clause—or trade taxes on some goods may be fixed at some exogenous level due to prior trade agreements. In the former case, we show that Proposition 1 continues to hold provided that marginal changes in imports are aggregated at the level at which trade taxes can vary, e.g. total imports of a given product from all WTO countries in the case of an MFN clause, as shown in equation (A.3). In the latter case, the existence of non-zero, but fixed trade taxes implies another source of distortions due to fiscal externalities, as

[9] Similarly, tariffs that are conditional on the use of production techniques, such as the rules-of-origin restrictions that often appear in trade agreements (Conconi et al., 2018), can be handled by defining goods on the basis of such techniques.

changes in the subset of trade taxes controlled by the government may now also affect the fiscal revenues generated by exogenous trade taxes, as described in equation (A.4). The same issue arises more broadly in the presence of other taxes, as illustrated in equation (A.7) in an environment that also allows producer taxes. For our estimates of β to be unbiased, such fiscal externalities should either be orthogonal to the changes in real earnings $\partial \omega / \partial m_n$ associated with different goods or explicitly controlled for in our regressions.

Trade Talks. The tariff formula in Proposition 1 hinges on a strict dichotomy between domestic households, whose utility the domestic government takes into account when setting trade taxes, and foreigners, who are absent from the government's problem in Definition 2. In practice, various rounds of trade negotiations and bargaining may lead governments to, at least partly, internalize the impact of their trade taxes on foreigners' welfare. Accordingly, it is common in the trade literature to model negotiated tariffs, such as those arising from GATT negotiations, as Pareto efficient from a world standpoint (e.g. Bagwell and Staiger, 2002).

As we show in Appendix A.2, from the point of view of Home, the only difference between the structure of Pareto efficient trade taxes that we consider and those that would arise from "trade talks" is the value of the coefficient in front of the terms-of-trade motive, $m \cdot \partial p^w / \partial m_n$ in equation (10). Under the assumption that the domestic government takes into account foreigners' real income, it is now equal to $1 - \lambda_F / \bar{\lambda}$ instead of 1, with λ_F the social marginal utility (still from the point of view of Home's government) of foreigners' income, as described in equation (A.10). The general logic behind our formula is unchanged. The key observation is that Home's government now not only values redistribution towards various domestic households, as reflected in $-\beta \cdot \partial(\omega - \bar{\omega}) / \partial m_n = \sum_h (1 - \lambda(h)/\bar{\lambda})(\partial \omega(h) / \partial m_n)$, but also redistribution towards foreigners, as reflected in $(1 - \lambda_F / \bar{\lambda})(\partial \omega_F / \partial m_n)$, with $\partial \omega_F / \partial m_n \equiv m \cdot \partial p^w / \partial m_n$ the change in foreigners' real income.[10] Since some of the tariffs that we consider in our empirical analysis have been negotiated, we will allow the coefficient in front of the terms-of-trade motive, $m \cdot \partial p^w / \partial m_n$, to differ from 1 whenever used as a control.[11]

[10]Note that if trade taxes are globally efficient, trade taxes imposed by the rest of the world should also be consistent with Home's Pareto weights. This observation is at the core of our empirical analysis in Adao et al. (2023b).

[11]More generally, if Home places heterogeneous weights on groups c of foreign countries (perhaps due to preferential trade agreements), this can be allowed for by controlling more flexibly for separate terms, $M_c \cdot \partial p^w / \partial m_n$, where M_c denotes the total imports from group c. A similar observation applies to changes in foreign welfare due to redistribution among foreign households from the same country. If Home places different weights on different households h located in c (perhaps due to political forces in c influencing

Other Distortions. Finally, Proposition 1 assumes that the only source of distortions are externalities in an otherwise perfectly competitive environment. In Appendix A.2, we show how general distortions due to imperfect competition may be incorporated in our tax formula. Since this formula reflects a necessary first-order consideration, this new source of distortions enters additively, as the extra social cost of firms' output distortions, as shown in equation (A.14). In the case where firms only produce a single good and the social marginal utility of income is equalized across households, it is simply equal to the change in the final output of the firm multiplied by the difference between its price and marginal cost, as is standard in the literature on misallocation. For our purposes, it is enough to note that such extra considerations would appear as part of our structural residual, like fiscal externalities, and would only matter to the extent that they are systematically correlated with changes in real earnings $\partial(\omega - \bar{\omega})/\partial m_n$.

3 Measuring the Sensitivity of Real Earnings to Imports

The goal of our empirical analysis is to use equation (10) to go from observed US trade taxes t to the Pareto weights β and, in turn, to explore what political considerations may be affecting the heterogeneity in such weights. Doing so requires measures of the sensitivity of real earnings to imports of any given good n, $\partial(\omega - \bar{\omega})/\partial m_n$, holding constant the imports of all other goods. Direct estimation without a priori restrictions would require estimating as many derivatives $\partial(\omega(h) - \bar{\omega})/\partial m_n$ as there are household-good pairs (h, n) in the US economy, which is infeasible. To arrive at such estimates we therefore propose to build a quantitative model of the US economy using a specific version of the general environment from Section 2 whose parameters have already been estimated for the US economy from plausibly exogenous variation in tariffs. We will then demonstrate that this estimated model can successfully account for the causal impact of observed tariff shocks on relative earnings, which raises confidence in the belief that the model can also be used to provide an accurate measure of $\partial(\omega - \bar{\omega})/\partial m_n$.

3.1 A Quantitative Model of the US Economy

The specific environment that we rely on for the rest of our analysis is an extension of the model in Fajgelbaum et al. (2020) (FGKK), which we will calibrate using data from 2017.

its trade negotiations with Home), then controls may be further broken down into $M_c(h) \cdot \partial p^w / \partial m_n$, with $M_c(h) \equiv y_c(h) - c_c(h)$ the next exports of that household. This is equally straightforward in theory, though data on $M_c(h)$ rather than M_c may be much harder to obtain in practice.

Regions, Sectors, Products, and Trade Partners. A domestic household h may live in one of many regions $r \in \mathcal{R}_H$ and work in one of many sectors $s \in \mathcal{S}$. Given data availability, we take the set of domestic regions $\mathcal{R}_H$ to be the 50 US states (plus the District of Columbia) and the set of sectors $\mathcal{S}$ to be 29 industries based on a combination of 2 and 3-digit NAICS industries.

We let H_{rs} denote the fixed number of households living in region r and working in sector s.[12] All households are endowed with labor, which they sell to firms f in that region and sector for a wage w_{rs}. Firms hire workers and buy intermediate goods from other domestic firms and foreigners in order to produce differentiated products $g \in \mathcal{G}_s$, which they sell to foreigners, other domestic firms, and households. The set of all products $\mathcal{G} \equiv \cup_{s\in\mathcal{S}}\mathcal{G}_s$ is based on the 6-digit HS system, resulting in 5,299 products with positive trade in 2017.

Foreigners may be located in one of many countries $i \in \mathcal{R}_F$. We take the foreign countries $\mathcal{R}_F$ to be the top 100 US trade partners, plus the rest of the world treated as a single country; the top 100 partners account for 99.0% of U.S. exports and 99.6% of its imports. A good n in the general notation of Section 2 either corresponds to labor from a given region-sector pair (r, s) or to an origin-destination-product triplet (o, d, g), where each origin o and destination d is either a domestic region r or a foreign country i. For future reference, we let $\mathcal{R} \equiv \mathcal{R}_H \cup \mathcal{R}_F$ denote the set of all locations.

Trade Taxes. In terms of policy instruments, we assume that there are no export taxes or subsidies. The only US trade taxes are specific import tariffs t_{ig} that may vary freely across foreign origins $i \in \mathcal{R}_F$ and products $g \in \mathcal{G}$.[13] All tariff revenues continue to be rebated uniformly across all households. Note that since a tradable good n corresponds to an origin-destination-product triplet, this implies that trade taxes are constrained to be equal across all domestic destinations, i.e. different US regions cannot impose different tariffs. As discussed in Section 2.4, our general formula still holds in this case provided that marginal changes in imports now refer to total changes in imports of product g from country i, $m_{ig} \equiv \sum_{r\in\mathcal{R}_H} m_{irg}$, where m_{irg} denotes bilateral imports to each region $r \in \mathcal{R}_H$, as described in equation (A.3).

[12] Following FGKK, our baseline specification does not allow for mobility across sectors and regions. As such, it should be thought of an approximation for the short-run impact of tariffs on earnings.

[13] In practice, the vast majority of import tariffs imposed by the United States are ad-valorem rather than specific. As already discussed in Section 2, there is no loss of generality in focusing on an environment where all import tariffs are assumed to be specific instead. One can always go from the competitive equilibrium with specific tariffs to one with ad-valorem tariffs by letting the specific tariffs be equal to the ad-valorem ones times the price of US imports (pre-tariff) in that equilibrium.

Sensitivity of Real Earnings to Imports. In this specific environment, for any household h located in region r and employed in sector s, the change in real earnings associated with an increase in imports of product g from a foreign country i reduces to

$$\frac{\partial \omega(h)}{\partial m_{ig}} = \frac{\partial w_{rs}}{\partial m_{ig}} - \sum_{o \in \mathcal{R}, v \in \mathcal{G}} c_{orv}(h) \frac{\partial p_{orv}}{\partial m_{ig}}, \tag{11}$$

where $c_{orv}(h)$ is the consumption of product v from origin o by household h from region r in the competitive equilibrium with trade taxes t observed in 2017, as we discuss further below, and p_{orv} denotes the domestic price of that good. The first term on the right-hand side, $\partial w_{rs}/\partial m_{ig}$, is the earnings channel, whereas the second term, $\sum_{o \in \mathcal{R}, v \in \mathcal{G}} c_{orv}(h)(\partial p_{orv}/\partial m_{ig})$, is the expenditure channel.

To compute the partial derivatives that enter (11), we first need to derive the Jacobian of wages, prices, and imports with respect to tariffs: $D_t\tilde{w} \equiv \{\partial \tilde{w}_{rs}/\partial t_{ig}\}$, $D_t\tilde{p} \equiv \{\partial \tilde{p}_{orv}/\partial t_{ig}\}$, and $D_t\tilde{m} \equiv \{\partial \tilde{m}_{jv}/\partial t_{ig}\}$. We can then solve for the Jacobian of wages and prices with respect to imports, $D_m w \equiv \{\partial w_{rs}/\partial m_{ig}\}$ and $D_m p \equiv \{\partial p_{orv}/\partial t_{ig}\}$, by using the fact that $D_m w = (D_t\tilde{w})(D_t\tilde{m})^{-1}$ and $D_m p = (D_t\tilde{p})(D_t\tilde{m})^{-1}$, respectively. Next, we describe the parametric restrictions that we impose on domestic technology, domestic preferences, and foreign offer curves to compute the previous Jacobian matrices. Further details about how we solve for a competitive equilibrium in this environment can be found in Appendix B.

3.2 Parametric Restrictions

Our parametric restrictions build on those in FGKK. Production and utility functions are nested CES, with the nesting structure chosen to allow a flexible pattern of substitution across origins, products, and sectors subject to the availability of production and trade data.

Domestic Technology. For each region $r \in \mathcal{R}_H$, destination $d \in \mathcal{R}_H \cup \mathcal{R}_F \equiv \mathcal{R}$, and product $g \in \mathcal{G}_s$ from sector $s \in \mathcal{S}$, there is a representative firm $f \in \mathcal{F}$ whose gross output $q(f)$ is equal to

$$q(f) = \theta_{rds}[\ell_{rs}(f)]^{\alpha_s} \prod_{k\in\mathcal{S}} [Q_{rk}(f)]^{\alpha_{ks}}, \tag{12}$$

$$Q_{rk}(f) = \left[\sum_{c=H,F} (\theta^c_{rk})^{\frac{1}{\kappa}} [Q^c_{rk}(f)]^{\frac{\kappa-1}{\kappa}} \right]^{\frac{\kappa}{\kappa-1}}, \tag{13}$$

$$Q^c_{rk}(f) = \left[\sum_{v\in\mathcal{G}_k} (\theta^c_{rkv})^{\frac{1}{\eta}} [Q^c_{rkv}(f)]^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{14}$$

$$Q^c_{rkv}(f) = \left[\sum_{o\in\mathcal{R}_c} (\theta^c_{orkv})^{\frac{1}{\sigma}} [q_{orv}(f)]^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \tag{15}$$

where $\ell_{rs}(f)$ denotes labor from region r and sector s used by firm f and $q_{orv}(f)$ denotes its use of intermediate inputs of product v from origin o delivered to region r.[14] As in FGKK, $\kappa \geq 0$ 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 domestic or foreign origins, within any given product. Since we only observe product-level trade flows between domestic regions and foreign countries, but not between pairs of domestic regions, we impose $\theta^H_{rkv} = \bar{\theta}^H_{rk}$ and $\theta^H_{orkv} = \bar{\theta}^H_{ork}$. Finally, we normalize the other shifters of input demand so that $\alpha_s + \sum_{k\in\mathcal{K}} \alpha_{ks} = \sum_{c=H,F} \theta^c_{rk} = \sum_{v\in\mathcal{G}_k} \theta^c_{rkv} = \sum_{o\in\mathcal{R}_c} \theta^c_{orkv} = 1$. Note that trade costs are implicitly embedded in demand shifters. If a product j from sector k is nontradable from an origin o to region r, then $\theta^c_{orkv} = 0$.

[14] In terms of the general notation of Section 2, the associated vector of net output $y(f)$ is obtained by entering gross output with a positive sign for good $n = (r, d, g)$ and entering all inputs with a negative sign. This vector is then feasible, $y(f) \in \Upsilon(z; f)$, if (12)-(15) hold. Note that there are no externalities in production in our quantitative model, a point we come back to below.

Domestic Preferences. In each region $r \in \mathcal{R}_H$, all households $h \in \mathcal{H}$ have the same preferences. Their utility $U(h)$ is equal to

$$U(h) = E(z,h) \prod_{s \in \mathcal{S}} [C_{rs}(h)]^{\gamma_s}, \tag{16}$$

$$C_{rs}(h) = \left[\sum_{c=H,F} (\theta^c_{rs})^{\frac{1}{\kappa}} [C^c_{rs}(h)]^{\frac{\kappa-1}{\kappa}} \right]^{\frac{\kappa}{\kappa-1}}, \tag{17}$$

$$C^c_{rs}(h) = \left[\sum_{g \in \mathcal{G}_s} (\theta^c_{rsg})^{\frac{1}{\eta}} [C^c_{rsg}(h)]^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{18}$$

$$C^c_{rsg}(h) = \left[\sum_{o \in \mathcal{R}_c} (\theta^c_{orsg})^{\frac{1}{\sigma}} [c_{org}(h)]^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \tag{19}$$

where $E(z,h)$ denotes the impact of externalities on the utility of household h. We assume that any positive consumption level $c_{org}(h) \geq 0$ is feasible, i.e. $\Gamma(z;h) = (\mathbb{R}^+)^N$ with N the total number of goods in the economy. Except for the Cobb-Douglas parameters $\{\gamma_s\}$ that may differ from $\{\alpha_{ks}\}$ in equation (12), note that all other demand shifters as well as elasticities in equations (17)-(19) are the same as in equations (13)-(15). That is, both domestic firms and households demand the same "sector composite," a standard data-driven restriction in quantitative trade models. In line with our treatment of technology, we normalize Cobb-Douglas parameters so that $\sum_{s \in \mathcal{S}} \gamma_s = 1$.

Foreign Offer Curve. For each foreign country $i \in \mathcal{R}_F$, domestic region $r \in \mathcal{R}_H$, and product $g \in \cup_{s \in \mathcal{S}} \mathcal{G}_s \equiv \mathcal{G}$, domestic imports m_{irg} and domestic exports x_{rig} satisfy

$$p^X_{irg} = \theta^{X,F}_{irg} (m_{irg})^{\omega_{X,F}}, \tag{20}$$

$$p^M_{rig} = \theta^{M,F}_{rig} (x_{rig})^{-\omega_{M,F}}, \tag{21}$$

where p^X_{irg} is the price received by foreign sellers of product g in country i that serves region r and p^M_{rig} is the price paid by foreign buyers of product g from region r in country i. The first elasticity $\omega_{X,F} \geq 0$ denotes the inverse of foreigners' export supply elasticity, whereas the second $\omega_{M,F} \geq 0$ denotes the inverse of their import demand elasticity.[15] Provided that either of these two elasticities is different from zero, then Home may affect

[15]Since a tradable good $n = (i,r,g)$ is origin-and-destination specific, there is no distinction between net and gross domestic imports; both are equal to m_{irg}. For the same reason, domestic exports x_{rig} are simply equal to minus net imports, i.e., $x_{rig} = -m_{rig}$. The vector of net imports $m = \{m_{irg}, -x_{rig}\}$ is then feasible, $m \in \Omega(p^w, z)$, if equations (20) and (21) hold.

its terms-of-trade $p^w \equiv \{p^X_{irg}, p^M_{rig}\}$ by restricting its imports and exports and the terms-of-trade motive $m \cdot (\partial p^w / \partial m_n)$ in equation (10) will be non-zero.

Externalities. Externalities only affect the utility of US households, and they do so leaving households' marginal rates of substitution unchanged, as can be seen from the impact of $E(z, h)$ in (16). This implies that the only role of externalities in the rest of our analysis will be to provide a rationale for, and interpretation of, the structural residual in our regressions. Accordingly, we do not impose any further restriction on the externalities included in the vector z and keep equation (5) as general as in Section 2.

3.3 Baseline Calibration

The last piece of information needed to evaluate the sensitivity of real earnings to imports in equation (11) are the values of the structural parameters that determine the competitive equilibrium of our quantitative model in 2017. These parameters comprise: the five elasticities, $\{\kappa, \eta, \sigma, \omega_{X,F}, \omega_{M,F}\}$; the technology shifters, taste shifters, and labor endowments, $\{\alpha_s, \alpha_{ks}, \gamma_s, \theta_{rds}, \theta^c_{rs}, \theta^c_{rsg}, \theta^c_{orsg}, \theta^{X,F}_{irg}, \theta^{M,F}_{rig}, H_{rs}\}$; and the US import tariffs, $\{t_{ig}\}$. We now describe how we calibrate each of them.

Elasticities. We set the values of the five elasticities $\{\kappa, \eta, \sigma, \omega_{X,F}, \omega_{M,F}\}$ equal to FGKK's estimates. For our purposes, this particular set of estimates is attractive because it relies on plausibly exogenous variation in US and foreign tariffs caused by Trump's trade war around 2017.[16] 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 $\sigma = 2.53$. In line with FGKK's empirical analysis, we further assume that foreigners' export supply to the US is perfectly elastic, so that $\omega_{X,F} = 0$, and set the inverse of foreigners' import demand elasticity to $\omega_{M,F} = 0.96$.

Technology shifters, taste shifters, and labor endowments. We set the values of the technology and taste shifters, $\{\alpha_s, \alpha_{ks}, \gamma_s, \theta_{rds}, \theta^c_{rs}, \theta^c_{rsg}, \theta^c_{orsg}, \theta^{X,F}_{irg}, \theta^{M,F}_{rig}, H_{rs}\}$ to match US data from 2017 on: value-added and employment by US region and sector; domestic trade flows by US region and sector; and international trade flows by US region, foreign

[16] Despite our quantitative model being more general than FGKK's original model—since it allows product differentiation across US regions—FGKK's estimating equations remain consistent with the parametric assumptions imposed in Section 3.2—since they rely on price variation due to import tariffs that are common across regions.

country, and product. In our baseline calibration, we further normalize all domestic prices $\{p_{odg}\}$ to one. This amounts to a choice of units of account that ultimately pins down the levels of $\{\theta_{rds}, \theta_{irg}^{X,F}, \theta_{rig}^{M,F}\}$, without further implications for the rest of our analysis.[17] We briefly describe the various data sources used in this procedure below and relegate further details about data construction and the specifics of our calibration to Appendix C.1.

Value-added and employment by US region and sector. We combine the BEA's national and regional accounts to obtain value-added at the region-sector level. We begin with nationwide data on value-added by sector, which are available from the BEA's make-use tables (before redefinitions) at the 3-digit NAICS level. Within each sector, we then assign these national value-added amounts to each region in proportion to its share of sectoral value-added in the BEA regional accounts.[18] We directly obtain total employment by region-sector from the regional accounts.

Domestic trade flows by US region and sector. To measure the value of flows from any domestic region-sector to any other, we begin with data on national sector-level input-output flows from the BEA. We then use Commodity Flow Survey microdata to form an estimate of the value of state-to-state domestic shipments for each producing sector (based on CFS industries that we concord to NAICS). Finally, we assign these producing sector shipment values proportionally across buyers in each state, assuming that the sectoral compositions of buying sectors' demands match national input-output shares and the sectoral composition of buying households' demands match national final demand.

International trade flows by US region, foreign country, and product. We obtain foreign imports and exports of products by US state from the US Census. These flows are available at the 6-digit HS level, which we concord to our sector classification, and are broken down by foreign country. Note that imports and exports of products by US state are only available for 18 manufacturing sectors, 1 agricultural sector, and 2 oil and mining sectors. For each of these sectors, we rescale state-level trade flows to match aggregate imports and exports in the national accounts. For the other 8 sectors in our analysis, we assume that all products are "non-tradable" and set international trade flows to zero.

[17] Given domestic prices $\{p_{odg}\}$, foreign export prices $\{p_{irg}^{X}\}$ and foreign import prices $\{p_{rig}^{M}\}$ are pinned down by the non-arbitrage condition (3).

[18] Reassuringly, within each sector, the BEA's national output data is very close to the sum of its regional data across regions.

US import tariffs. We also use US Census data to calculate the applied ad valorem equivalent (AVE) tariff charged by the United States on each HS6 product g from each foreign country i in 2017. We take the ratio of calculated duties to the FOB import value, which we denote $t_{ig}^{\text{ad-valorem}}$, as the AVE tariff for a given product-country pair. Under our price normalization, the associated specific import tariff is therefore equal to $t_{ig} = t_{ig}^{\text{ad-valorem}}/(1 + t_{ig}^{\text{ad-valorem}})$. For a given product g, t_{ig} may differ across origin countries due to country i being part of a preferential or regional trade agreement with the United States—e.g. the Generalized System of Preferences or NAFTA—and non-MFN ("column two") treatment of non-WTO members.

3.4 Model-Implied Sensitivity of Real Earnings to Imports

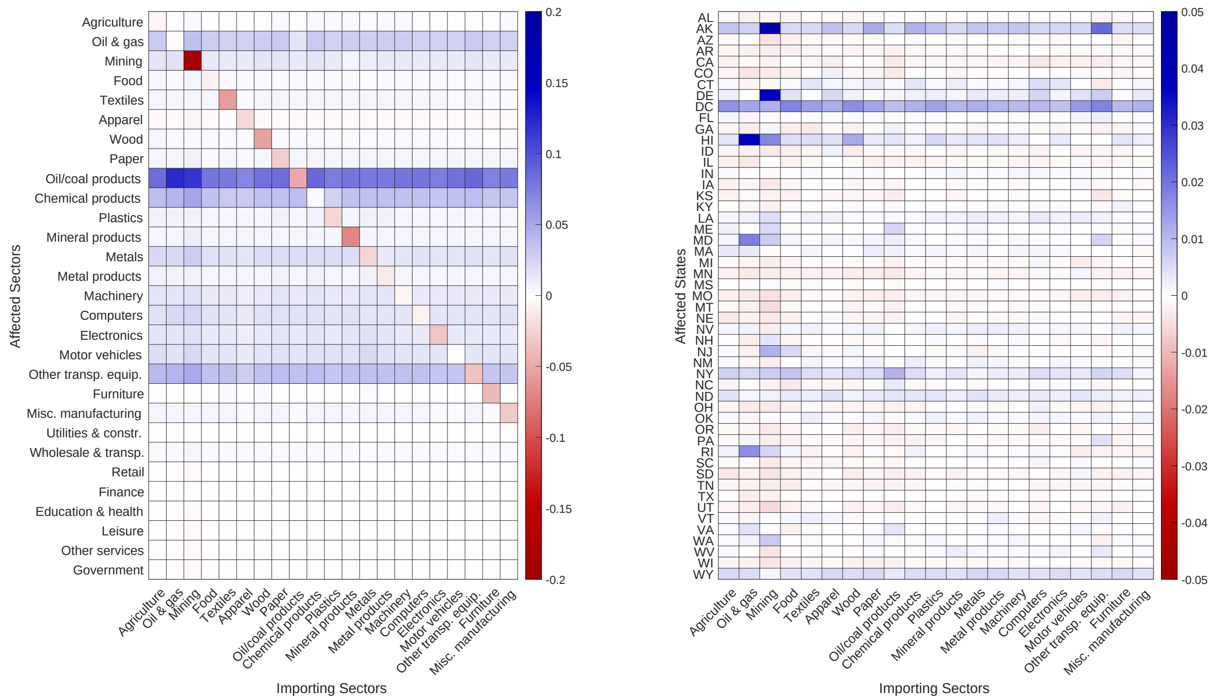
Given the parametric restrictions from Section 3.2 and the calibration from Section 3.3, we can solve for the competitive equilibrium of our quantitative model and compute the changes in real earnings associated with imports using equation (11). For each region-sector (r,s) and each country-product (i,g), we let $\partial\omega_{rs}/\partial m_{ig}$ denote the change in real earnings associated with imports of product g from country i for all households living in region r and working in sector s. The resulting Jacobian matrix $\{\partial\omega_{rs}/\partial m_{ig}\}$ has $51 \times 29 = 1,479$ rows, one for each region-sector pair $(r,s) \in \mathcal{R}_H \times \mathcal{S}$, and $5,299 \times 101 = 535,199$ columns, one for each country-product pair $(i,g) \in \mathcal{R}_F \times \mathcal{G}$.

We will use the entries of the Jacobian matrix $\{\partial\omega_{rs}/\partial m_{ig}\}$ to construct the right-hand side variables in our regressions. To help visualize the variation that will allow us to identify Pareto weights in Section 4, Figure 2 summarizes how changes in real earnings across sectors $s \in \mathcal{S}$ and regions $r \in \mathcal{R}_H$ are differentially affected by changes in imports from various tradable sectors $k \in \mathcal{S}^T$. In Figure 2a, each cell (s,k) reports the average change in real earnings $\partial(\omega_s - \bar{\omega})/\partial m_k$ for households employed in sector s associated with imports of goods in sector k minus the average change in real earnings for all US households.[19] Red colors, which indicate negative entries, are primarily on display when $s = k$. This is the result of the natural force of protection: US households tend to gain less from an increase in imports in their own sectors, relative to the US average, since the firms employing them also have to compete directly against foreign goods. The few

[19] When taking averages across imported products from any given sector k, we restrict ourselves to country-pair products (i,g) whose value of US imports in 2017 is greater than \$100,000, which leaves us with a total of 71,655 country-product pairs across all sectors. These are the same country-product pairs that we will focus on in the empirical analysis of Section 4. Denoting $\mathcal{N}_k$ the set of country-product pairs (i,g) that are above that cut-off in sector k, we therefore have $\frac{\partial(\omega_s - \bar{\omega})}{\partial m_k} = \frac{1}{|\mathcal{N}_k|}\sum_{(i,g)\in\mathcal{N}_k}\left[\sum_{r\in\mathcal{R}_H}\frac{H_{rs}}{H_s}\frac{\partial\omega_{rs}}{\partial m_{ig}} - \sum_{r\in\mathcal{R}_H, s'\in\mathcal{S}}\frac{H_{rs}}{H}\frac{\partial\omega_{rs'}}{\partial m_{ig}}\right]$, with H_s the total US employment in sector s.

Figure 2: Sensitivity of real earnings to imports

(a) Across sectors, $\partial(\omega_s - \bar{\omega})/\partial m_k$ **(b)** Across regions, $\partial(\omega_r - \bar{\omega})/\partial m_k$



Notes: Figure 1a plots estimates of how a marginal change in imports of goods in the sector shown on the x-axis affects the difference between the average real earnings of households employed in each of the sectors shown on the y-axis and the average real earnings of all US households. Figure 1b plots the same estimates for the average real earnings of households living in each of the region shown on the y-axis. Import units are chosen so that each cell reports the 2017 dollar change in real earnings associated with a one million 2017 dollar increase in US import values.

exceptions to this finding (with blue colored entries on the diagonal) are cases where, at this level of aggregation, imported intermediate products within the industry are more valuable to firms than is the protection offered by lower imports of competing foreign products. Turning to $s \neq k$, we see that households in non-tradable sectors (in the bottom rows) also tend to gain less from imports relative to the US average. This reflects the fact that intermediate inputs from tradable sectors tend to be a much smaller fraction of total costs in non-tradable sectors: 6.9% on average compared to 40.4% for tradable sectors.

Figure 2b turns to analogous effects across states. Each cell (r, k) now reports the average change in real earnings for households living in region r associated with imports from sector k minus the average change in real earnings for all US households, which we denote $\partial(\omega_r - \bar{\omega})/\partial m_k$. The three most positive values are the impact of mining imports on Alaska and Delaware, and the impact of oil and gas imports on Hawaii. Increase in mining imports tends to increase wages in Alaska, whereas mining imports in Delaware and oil and gas imports in Hawaii tend to reduce the cost of living. This suggests that the heterogeneity in the impact of imports across states does not merely reflect differences in industry composition. Although the magnitudes of state-level impacts shown in Figure 2b are somewhat less dispersed than the sector-level impacts in Figure 2a, this masks variation in the impacts of imports within the same sector, which are averaged in the figures. When comparing the standard deviations of $\partial(\omega_s - \bar{\omega})/\partial m_{ig}$ and $\partial(\omega_r - \bar{\omega})/\partial m_{ig}$ across all origin-product pairs (i, g), we find that the standard deviation for states is 2.7 times higher on average for regions than for sectors sectors.[20] In other words, the typical import induces more than twice as much redistribution across states as across sectors.

3.5 Validating Model-Implied Sensitivity of Real Earnings to Imports

Before turning to the identification of welfare weights by combining our tariff formula with the values of $\{\partial(\omega_{rs} - \bar{\omega})/\partial m_{ig}\}$ implied by our quantitative model, we propose to validate our model's predictions. Although one cannot directly estimate the Jacobian matrix $\{\partial(\omega_{rs} - \bar{\omega})/\partial m_{ig}\}$—which would amount to separately identifying $1,479 \times 535,199$ local causal effects—one can focus on a subset of exogenous changes in imports that have been observed in the data and ask whether, for these changes, the causal responses of earnings predicted by our model are "close" to observed ones.

Given our objective to identify US welfare weights in 2017, the ideal experiment would focus on plausibly exogenous tariff changes affecting the US economy around that time. As a proxy for such an experiment, we follow FGKK by using the tariff changes implemented in 2018 by the Trump administration, as well as the retaliatory tariffs applied by US trading partners. Following Adao et al. (2023a) (ACD) we then propose to put our quantitative model to the test by comparing predicted and observed changes in the variable of interest, up to a projection on an instrumental variable (IV) constructed from the previous exogenous tariff changes. Under the null that our quantitative model's predictions are correct, the two projections should be the same.[21]

[20] This is the opposite of what one would expect in a model where changes in real earnings are determined at the sector-level and changes in real earnings at the region-level are purely compositional. Appendix Figure D.1 reports these standard deviation statistics separately for each sector and state.

[21] Estimates of elasticities from FGKK rely on the impact of the same exogenous tariff changes on the prices and quantities of imports to and exports from the United States Since these estimates are already used in the calibration of our model, one may wonder whether additional testing can be conducted. As discussed in ACD, the answer is yes. The reason is that our model relies additionally on a large number of untested assumptions, from the structure of domestic input-output linkages to a lack of factor mobility across regions and sectors. ACD's IV-based test implicitly sheds light on the overall credibility of those assumptions by using extra moment conditions, distinct from those already used in estimation. We also

Formally, we estimate the following two linear regressions:

$$(\Delta w_{rs})_{\text{obs.}} = \alpha_{0,\text{obs.}} + \alpha_{1,\text{obs.}} z_{rs} + \varepsilon_{rs,\text{obs.}}, \tag{22}$$

$$(\Delta w_{rs})_{\text{pred.}} = \alpha_{0,\text{pred.}} + \alpha_{1,\text{pred.}} z_{rs} + \varepsilon_{rs,\text{pred.}}, \tag{23}$$

where $(\Delta w_{rs})_{\text{obs.}}$ is the change in earnings per worker observed in region r and sector s between 2017 and 2019, $(\Delta w_{rs})_{\text{pred.}}$ is the counterpart predicted by our model in response to Trump's trade war, and z_{rs} is a shift-share IV whose shifters are the (demeaned) changes in US and foreign tariffs and the shares are the associated derivatives of changes in earnings per worker in region r and sector s.[22] Changes in earnings per worker $(\Delta w_{rs})_{\text{obs.}}$ are measured as changes in the ratio of value-added to employment in region r and sector s.[23] Both regressions are weighted by initial employment, consistent with our tariff formula that requires employment-weighted changes in earnings, as can be seen from equation (24). Because of other shocks occurring between 2017 and 2019, $(\Delta w_{rs})_{\text{obs.}}$ and $(\Delta w_{rs})_{\text{pred.}}$ may differ, but since these shocks are assumed to be orthogonal to tariff changes, the difference between the two regression coefficients $\alpha_{1,\text{obs.}}$ and $\alpha_{1,\text{pred.}}$ should be zero.

Table 1 reports our estimates. Columns (1) and (2) show that both observed and predicted changes in earnings per worker are positively related to our IV, with precisely estimated coefficients close to one. Column (3), in turn, reports the difference between the two coefficients, which corresponds to the coefficient of a regression of $(\Delta w_{rs})_{\text{obs.}} - (\Delta w_{rs})_{\text{pred.}}$ on the IV. Estimates indicate that we cannot reject that the two projections are the same at usual levels, with a p-value of 0.74 for the test that the estimated coefficient in column (3) is zero.[24] Thus the causal impact of Trump's trade war on earnings per workers across US sectors and regions is consistent with that predicted by our model.

Our empirical strategy requires tariff shocks to be orthogonal to other shocks driving changes in earnings per worker during the trade war period of 2017-2019. To evaluate the credibility of this assumption, column (4) investigates whether sector-state pairs differentially affected by the trade war were in similar trajectories in the pre-war period. Specif-

note that our test relies on responses for outcomes that FGKK do not use in estimation; namely, earnings per worker across sectors and states. This should further ease concerns of mechanical fit.

[22]Hence, up to demeaning, z_{rs} is a first-order approximation to $(\Delta w_{rs})_{\text{pred.}}$. Specifically, we set $z_{sr} \equiv \sum_{i,g} (\partial \tilde{w}_{rs} / \partial t_{ig}) \left(\Delta t_{ig} - \Delta \bar{t} \right) + \sum_{i,g} (\partial \tilde{w}_{rs} / \partial t_{ig}^F) \left(\Delta t_{ig}^F - \Delta \bar{t} \right)$, where $\{t_{ig}^F\}$ are the (specific) tariffs imposed by a foreign country i on US exports of product g and $\Delta \bar{t}$ is the average across all tariff changes between 2017 and 2019. Note that equation (21) implies $\partial \tilde{w}_{rs} / \partial t_{ig}^F = \partial \tilde{w}_{rs} / \partial (1/\theta_{rig}^{M,F})$. In line with our analysis in Section 3.4, we only include tariff changes for country-product pairs with at least \$100,000 of US imports or exports in 2017, yielding 179,639 tariff shifters (71,655 for imports and 107,984 for exports).

[23]Due to lack of region-level price data, we focus on changes in nominal rather than real earnings.

[24]Appendix Figure D.2 reports bin-scatter plots illustrating the specifications in columns (1)-(3) of Table 1.

Table 1: Observed vs. predicted changes in earnings during Trump's trade war

Outcome:	Log-change in				
	earnings per worker				employment
	observed	predicted	obs. - pred.	pre-war	observed
	(1)	(2)	(3)	(4)	(5)
Estimate	1.373	1.180	0.193	-0.242	-0.314
St. error	(0.559)	(0.018)	(0.576)	(0.234)	(0.249)
p-value	0.014	0.000	0.738	0.301	0.208
R^2	0.010	0.995	0.000	0.000	0.002

Notes: Sample of 1348 sector-state pairs with positive employment and value-added. All specifications include a constant and are weighted by employment in 2017. Earnings per worker measured as value-added in a region-sector pair divided by employment in that same region-sector. Observed outcomes in columns (1), (3) and (5) correspond to changes between 2017 and 2019; predicted outcome in column (3) is our model's prediction for the impact of US and foriegn tariff changes between 2017 and 2019; and pre-war outcome in column (4) corresponds to observed changes between 2015 and 2017. Standard errors in parentheses computed with ACD's version of inference for shift-share specifications clustered by HS6 product.

ically, we implement the regression in (22) using instead observed changes between 2015 and 2017. Lending support to the orthogonality condition embedded in our IV-based test, pre-war changes in outcomes are not correlated with changes in US and foreign tariffs during the trade war.

Finally, we note that according to our quantitative model, earnings per worker should vary because of changes in total earnings, not changes in the number of workers, which is assumed to be fixed. Since we measure earnings per capita as value-added divided by employment, one may worry that observed changes in earnings per worker are actually driven by changes in employment rather than value-added, in contrast to what our model predicts. Column (5) investigates this issue by returning to (22), but using the observed changes in employment as the dependent variable. Reassuringly, we find a small, non-significant estimated coefficient for employment.[25]

[25]This finding echoes those of Autor et al. (2023) and Flaaen and Pierce (2021), who estimate small US employment effects due to the Trump trade war when using cross-region and cross-sector variation, respectively.

4 Putting the Formula to Work

4.1 Empirical Specification

We now return to the empirical specification suggested by Proposition 1: that a regression of tariffs on a measure of the sensitivity of households' real earnings to imports will reveal estimates of the social marginal return of transfers to households, and hence the strength and nature of distributional motives for protectionism.

For empirical purposes, we assume that welfare weights are an additively separable function of the "socioeconomic groups" $j \in \mathcal{J}$ to which households $h \in \mathcal{H}$ may belong,

$$\beta(h) = \sum_{j \in \mathcal{J}} \text{Dummy}_j(h) \times \beta_j,$$

where $\text{Dummy}_j(h)$ is an indicator variable that takes the value of one if household h is a member of group j and zero otherwise, and β_j is the social marginal return of transfers to members of group j. Note that any household can be a member of multiple groups. Note also that since $\sum_{h \in \mathcal{H}} \beta(h) = 1$, as established in Section 2, we must also have $\sum_{j \in \mathcal{J}} H_j \beta_j = 1$, with $H_j \equiv \sum_{h \in \mathcal{H}} \text{Dummy}_j(h)$ the number of households in group j.

In our baseline analysis, we focus on the scope for returns that are based on households' sectors and regions.[26] In particular,we model socio-economic groups that are defined according to two considerations: "working in sector s," with welfare weights $\{\beta_s\}_{s \in \mathcal{S}}$, and "residing in region r," with welfare weights $\{\beta_r\}_{r \in \mathcal{R}_H}$, respectively.[27] This implies that, using the notation from Section 3, we can write our general tariff formula (10) as

$$t_{ig} = -\sum_{s \in \mathcal{S}} \beta_s H_s \frac{\partial(\omega_s - \bar{\omega})}{\partial m_{ig}} - \sum_{r \in \mathcal{R}_H} \beta_r H_r \frac{\partial(\omega_r - \bar{\omega})}{\partial m_{ig}} + \text{Controls}_{ig} + \varepsilon_{ig}, \tag{24}$$

where t_{ig} denotes the 2017 specific US tariff on good g from foreign country i, which we measure as $t_{ig} = t_{ig}^{\text{ad-valorem}}/(1 + t_{ig}^{\text{ad-valorem}})$, with $t_{ig}^{\text{ad-valorem}}$ the ratio of calculated duties to the FOB import value for each ig pair, as discussed in Section 3.3.

[26]This interest is motivated by the contrasting predictions of models based on sectoral approaches, such as Grossman and Helpman (1994), and regional approaches, such as Ma and McLaren (2018).

[27]In the model of Section 2, each household resides in a single region and supplies labor to a single sector from that region, so changes in household's real incomes may only vary across region-sector pairs. As a result, we cannot identify welfare weights for groups formed from finer partitions than region-sector combinations (such as, for example, separate age groups of workers within Arizona's apparel sector). While it is possible, in principle, to estimate separate values of β_j for each region-sector combination, we pursue a version with separate sector- and region-specific effects for reasons of parsimony (i.e. $|\mathcal{R}_H| + |\mathcal{S}|$ parameters to estimate rather than $|\mathcal{R}_H| \times |\mathcal{S}|$).

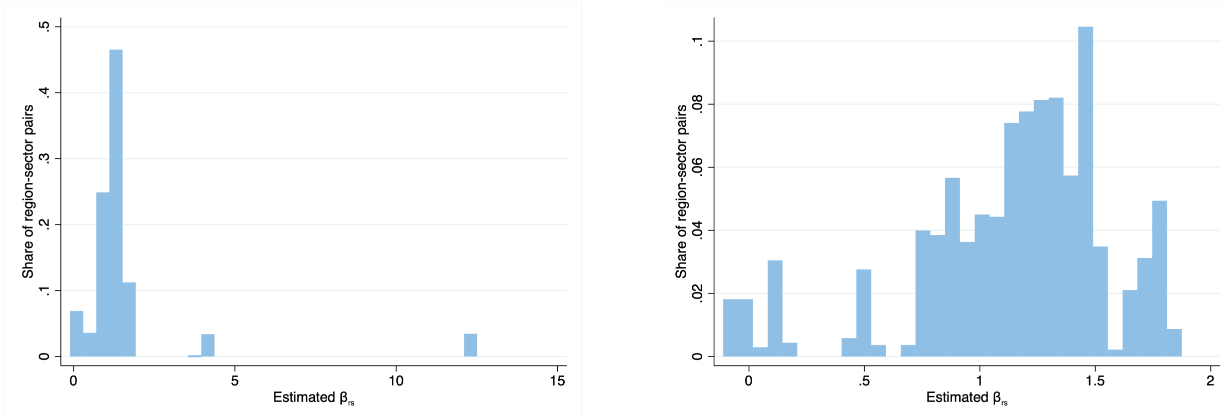
According to (24), the tariff t_{ig} is a function of four terms. The first two terms are our objects of primary interest. They capture redistribution towards households based on their sectors of employment and state of residence. The unknown sets of parameters, β_s and β_r, represent the social marginal return of transfers to the households in any given sector s and region r. The corresponding regressors $\partial(\omega_s - \bar{\omega})/\partial m_{ig}$ and $\partial(\omega_r - \bar{\omega})/\partial m_{ig}$ capture the sensitivity of the average real earnings of households working in a sector s or residing in a region r (relative to the US average $\bar{\omega}$) to a change in the quantity of imports m_{ig} in product g from foreign country i. The measurement of such sensitivities was the focus of Section 3, with Figure 2 summarizing the variation in these regressors. The third term in (24) refers to additional factors that we control for, beyond sector- and region-based redistributive motives. Our baseline analysis will populate this set with an intercept and the term $m \cdot (\partial p^w/\partial m_{ig})$, which captures terms-of-trade motives for trade protection. Finally, the fourth term ε_{ig} captures the impact of trade protection on distortions as well as any measurement error in trade taxes or misspecification. This term is unobserved and will constitute the error term in our regressions.

We begin by estimating a version of equation (24) via OLS. This requires that $\partial(\omega_j - \bar{\omega})/\partial m_{ig}$, for any $j = r, s$, is uncorrelated with the residual ε_{ig}, after controlling for an intercept and terms-of-trade motives. One potential concern with such an orthogonality requirement derives from measurement error in overall trade taxes. If, in addition to tariffs, there are non-tariff measures (NTMs) that also create extra tax revenues, the associated fiscal externalities would also be part of ε_{ig} and may be systematically correlated with tariffs. A second threat to the validity of our estimates would arise if the terms-of-trade motives are misspecified because Home puts different welfare weights on different foreign countries, implying that the aggregate term $m \cdot (\partial p^w/\partial m_{ig})$ would insufficiently control for terms-of-trade motives. A third concern—prominent in the existing empirical literature on trade policy (e.g. Trefler, 1993 and Goldberg and Maggi, 1999)—is reverse causality between tariffs and imports. Section 4.3 discusses strategies for assessing the potential for bias in our estimates due to these three concerns.

A distinct challenge arises from the component of tariffs that may derive from attempts to correct externalities—the term $\epsilon \cdot (\partial z/\partial m_{ig})$ in equation (10). The plausibility of $\partial(\omega_j - \bar{\omega})/\partial m_{ig}$ being uncorrelated with $\epsilon \cdot (\partial z/\partial m_{ig})$ across all ig inherently depends on what type of externalities one believes are more important empirically. For instance, in the case where the consumption of various imported goods may generate different health hazards, so that $z = \{m_{ig}\}$ and the externality experienced by each household is $E(\{m_{ig}\}, h) = \sum E_{ig} m_{ig}$, as is often considered in the product standards literature, our exclusion restriction requires no systematic correlation between health damage E_{ig} and the

Figure 3: Distribution of estimated welfare weights

(a) Full distribution **(b)** Truncated distribution



Notes: Figure 3a displays the distribution of all estimates of region-sector welfare weights $\hat{\beta}_{rs}$. Figure 3a does the same for values truncated at $\hat{\beta}_{rs} \leq 2$.

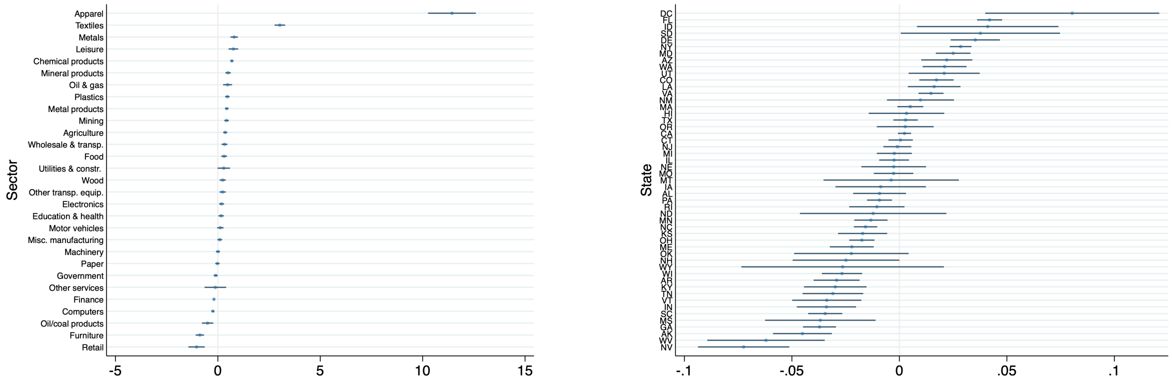
sensitivity of real earnings with respect to imports from that same country-product pair ig. A second type of externality that has featured prominently in the study of distortion-correcting tariff policy concerns foreign externalities due to carbon emissions (e.g. Kortum and Weisbach, 2021 and Hsaio, 2022), which are a function of total production abroad and work through the world price p^w. While the vector $\partial p^w / \partial m_{ig}$ is too high-dimensional to control for directly, it seems likely that our flexible approach to controlling for terms-of-trade motives, discussed below, may do much to mitigate this concern. Finally, in the case of social identity in Grossman and Helpman (2021), the psychosocial cost externality is assumed to be a linear function of changes in others' real earnings. So estimates of β_j must be biased, although in this case they can still be interpreted as the sum of the direct impact of a transfer to a household and the indirect impact via its effects on other households' psychosocial utility.

4.2 Baseline Estimates

We begin with OLS estimates of equation (24), which delivers estimates of β_s for each sector and β_r for each region. For any given household who works in sector s and reside in region r, the estimated welfare weight is therefore equal to $\hat{\beta}_{rs} \equiv \hat{\beta}_s + \hat{\beta}_r$. The distribution of these estimates is shown in Figure 3. It ranges from 12.5 in Apparel in DC to -0.11 in Retail in Nevada. Remarkably, despite the wide range of these estimates, all but 48 out of 1,479 of the welfare weights $\hat{\beta}_{rs}$ we estimate are positive and for none of the negative

Figure 4: Estimates of welfare weights across sectors and regions

(a) $\hat{\beta}_s$ estimates **(b)** $\hat{\beta}_r$ estimates



Notes: Panel (a) displays estimates of the marginal social return, β_s, for each sector s, as obtained from equation (24) and normalized such that the mean of $\hat{\beta}_s$ across s is zero. Panel (b) displays estimates of the marginal social return, β_r, for each region r, as obtained from equation (24) and normalized such that the mean of $\hat{\beta}_r$ across r is zero. Light blue dots correspond to point estimates and bars denote 95% confidence intervals. Standard errors are clustered at the product-level.

ones—all of which are in the retail sector—can we reject that they are positive at standard confidence levels. This lends credence to the Pareto efficiency assumption that underlies our revealed preference approach.[28]

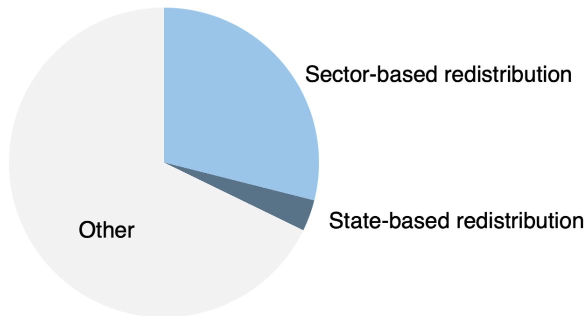
We next turn to the estimates of the marginal social returns, $\hat{\beta}_s$ and $\hat{\beta}_r$, themselves. Figure 4a presents the sector-based estimates $\{\hat{\beta}_s\}$ normalized such that their employment-weighed mean across sectors is zero.[29] In line with the results displayed in Figure 3, the estimates range from 11.4 for Apparel to -1.04 for Retail, and while Apparel is a clear outlier, even the second-largest value (3.0 for Textiles) is considerably higher than that of Retail.[30] Not surprisingly, Apparel has the largest ad-valorem average tariffs of any sector (9.8%) by a wide margin, followed by Textiles (5.4%). Retail, on the other hand, is downstream of these protected sectors, helping to explain its smaller welfare weight. The displayed 95% confidence intervals (with standard errors clustered at the product level) also indicate that, for most sectors, the estimate of $\hat{\beta}_s$ is statistically significantly different from zero (i.e. the average) at standard levels. More broadly, the 90-10 difference is around 1.6, implying that the social return from rebating a dollar of tax revenue (obtained via a uniform lump-sum tax) to households at the 90th percentile is more than twice as

[28] As in other areas of public finance, e.g. Werning (2007), Pareto efficiency is—in our setting—equivalent to the condition that all Pareto weights are positive.

[29] A normalization, such as this one, is necessary given that, even though $\hat{\beta}_{rs} = \hat{\beta}_r + \hat{\beta}_s$ is identified, the separate attribution of $\hat{\beta}_{rs}$ to either $\hat{\beta}_r$ or $\hat{\beta}_s$ is not.

[30] Appendix Figure D.4 contains a version of Figure 4 without Apparel for greater clarity.

Figure 5: Decomposition of variance in tariffs



Notes: This figure plots the share of variance in US tariffs t_{ig} in 2017 that can be explained, according to estimates of equation (24), due to each of three components: redistribution based on households' sector of employment; redistribution based on households' state of residence; and other factors. The decomposition of variance reported is computed using the Owen-Shapley method.

large as the return from rebating that same dollar to households at the 10th percentile.[31] Since a world in which trade protection is not used to achieve distributional goals at all—for example, because such goals can be achieved via other tax instruments or legislative pork—would have no welfare weight dispersion, this finding underscores a clear sense in which trade policy is very far from distribution-neutral.[32]

Turning to the estimates of region-specific effects $\{\hat{\beta}_r\}$, these are displayed in Figure 4b, with each region r corresponding to one of the 50 states, plus the District of Columbia. In relative terms, there is considerable spread, from DC's value of 0.08 to Nevada's value of -0.07. And these state-specific estimates are again significantly different from zero (and hence their normalized average value) in the majority of cases. However, they are of a strikingly smaller scale than the sector-specific estimates $\hat{\beta}_s$ in Figure 4.[33] This suggests that most of the observed variation in US tariffs may be accounted for by sector- rather than region-based considerations.

To quantify the explanatory power of redistributional motives, in general, and sector- and region-based consideration, in particular, we carry out an Owen-Shapley regression

[31] Equivalently, the 90-10 difference being around 1.6 implies that the social marginal value of *transferring* a dollar from households at the 10th percentile to households at the 90th percentile is equal to the social marginal value of *receiving* 1.6 dollars and uniformly rebating it to all households.

[32] For the interested reader, Appendix Figure D.3a plots the composition-adjusted estimated sector welfare weight defined as $\tilde{\beta}_s \equiv \hat{\beta}_s + \sum_r (H_{sr}/H_s)\hat{\beta}_r$, again normalized such that the mean of $\tilde{\beta}_s$ across sectors is zero, and with the displayed confidence intervals on each $\tilde{\beta}_s$ estimate calculated from those on $\{\hat{\beta}_s\}$ and $\{\hat{\beta}_r\}$. The composition-adjusted estimates $\tilde{\beta}_s$ are extremely highly correlated with the original estimates $\hat{\beta}_s$, implying that the effect of adjusting for differences in state composition across sectors is minor.

[33] Given the considerably larger variance of $\hat{\beta}_s$, it is no surprise to see that the composition-adjusted estimates of region effects $\tilde{\beta}_r$, which we report in Appendix Figure D.3b, are only weakly correlated with the raw values $\hat{\beta}_r$, and also that the variance of $\hat{\beta}_r$ is lower than that of $\tilde{\beta}_r$.

decomposition. The results of this decomposition are displayed in Figure 5. Two findings are evident. First, although we aim to explain the variation in 71,655 tariff lines using changes in real earnings across 51 regions and 29 sectors, the combination of the sector- and region-based redistributional motives—i.e., the first two sets of regressors in (24)—accounts for about one third (30%) of the total variation in US trade policy. Second, sector-based motives for redistribution explain the lion's share of total redistributive motives (27% versus 3%), implying that region-based considerations are indeed relatively minor.[34]

4.3 Sensitivity Analysis

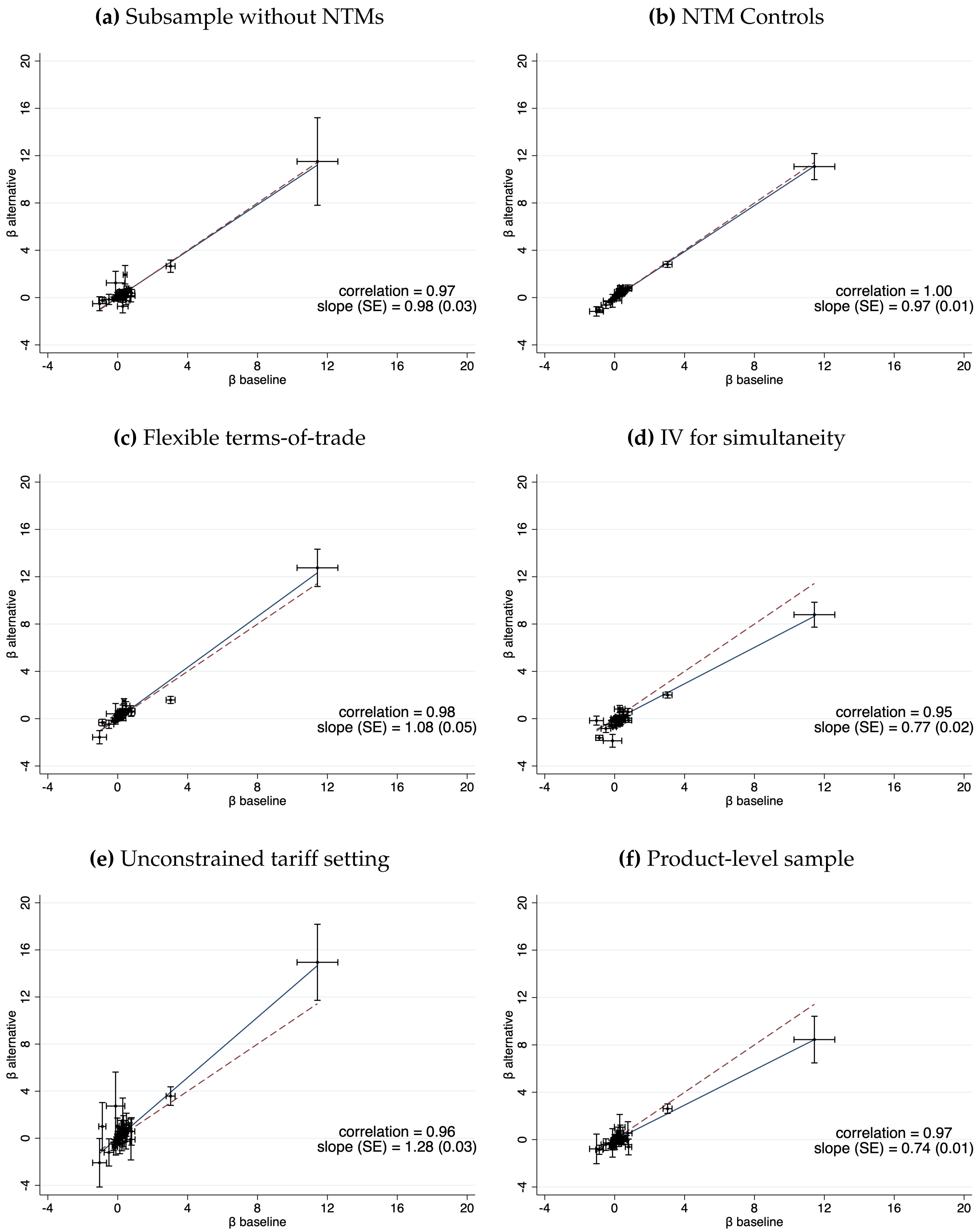
As discussed above, the baseline estimates reported in Section 4.2 were obtained under a number of assumptions that we now probe further. Figure 6 summarizes the resulting estimates of $\hat{\beta}_s$ and $\hat{\beta}_r$ that we obtain, for each sector s and region r, under six alternative specification choices. In each case we display a scatter plot of our baseline values of these estimates (on the x-axis) against estimates of the same objects obtained under alternative assumptions (on the y-axis).[35]

We begin by considering the role of non-tariff measures (NTMs). If imports of product g from origin i generate revenue via not only the tariff t_{ig} but also through the use of various NTMs, then there would be an additional fiscal externality associated with variations in m_{ig} that would enter the error term ε_{ig} in equation (24). Such a feature would lead to bias in our estimates of $\hat{\beta}_s$ and $\hat{\beta}_r$ if, for example, Home's government systematically raise NTMs on the goods for which they have negotiated lower tariffs. To assess the quantitative relevance of this point, we conduct two exercises. First, as reported in Figure 6a, if we focus on the subsample of 27% of observations in which (according to the TRAINS database) no NTM is in place, and in which (according to the Temporary Trade Barriers database, Bown et al. (2020)), no antidumping or countervailing duties apply, we find similar estimates. In particular, there is a correlation of 0.97 between baseline and control, with a regression slope of 0.96. Second, we can consider the possibility that each

[34]Using the same Shapley regression decomposition, one can also asses the importance of terms-of-trade considerations. We find that 7% of the variance is explained by the terms-of-trade motive $m \cdot (\partial p^w / \partial m_{ig})$. This reflects in part the small coefficient that we estimate in front of this regressor, a coefficient that is significantly different from one in all our regressions and consistent with the idea that negotiated US tariffs may partly internalize terms-of-trade considerations on the rest of the world.

[35]Appendix Table D.1 contains a deeper exploration of the results of such sensitivity analyses, reporting comparisons between baseline and alternative estimates of, variously, sector-specific estimates $\hat{\beta}_s$, region-specific estimates $\hat{\beta}_r$, and estimates that drop the outlier Apparel sector. In all such cases we find that the conclusions we discuss here, in relation to Figure 6 for the pooled set of sector and region estimates, are extremely similar when examining such alternatives. In addition, Appendix Figure D.5 contains a version of Figure 6 that omits the Apparel sector estimate for greater clarity.

Figure 6: Sensitivity analysis



Notes: Each figure displays the relationship between baseline estimates (of $\hat{\beta}_s$ and $\hat{\beta}_r$ across all sectors s and regions r) on the x-axis and estimated values obtained under alternative assumptions (described in the text) on the y-axis. The solid blue line illustrates the line of best fit (whose slope and standard error are reported) and the dashed red line indicates the 45-degree line. Bars indicate 95% confidence intervals on each estimate.

type of NTM features its own propensity to generate tax revenue. If this is the case then the fiscal externality effect of NTMs can be controlled for via a set of indicator variables for whether each of type of NTM is applied to imports of product g from origin i or not.[36] Figure 6b demonstrates that our estimates of welfare weights are highly insensitive to the addition of such controls.[37] An additional robustness exercise, reported in Appendix Figure D.6, confirms that our results are insensitive to adding to t_{ig} an estimate for the average antidumping and countervailing duties that apply to product g from origin i in 2017.

A second category of potential violation of the orthogonality restriction behind the OLS estimates presented in Section 4.2 concerns the way in which our baseline specification controls for the terms-of-trade motive, via the term $m \cdot (\partial p^w / \partial m_{ig})$. This procedure is sufficient if Home places the same welfare weight on each foreign country. But if these weights differ across groups of countries, e.g. depending on whether foreign countries are part of a preferential trade agreement with the US or not, then the appropriate set of controls would involve $m^c \cdot (\partial p^w / \partial m_{ig})$, where $m^c \equiv \{m^c_{i'g'}\}$ denotes the vector of imports into Home originating from a given group of countries c, for every such relevant group. Figure 6c presents results from an extreme version of this in which we control for 101 distinct terms-of-trade motives, one for each of the 101 foreign countries in our analysis. We again see that our estimates of $\hat{\beta}_s$ and $\hat{\beta}_r$ are largely unaffected (e.g. the correlation of these estimates with our baseline values is 0.96) by this flexible approach to the terms-of-trade motive.[38]

The third potential concern about the OLS estimates discussed above arises from the fact that tariffs (the dependent variable) may have their own causal impact on imports and, in turn, the sensitivity of imports on real earnings (the independent variable). Si-

[36]In particular, we use a set of five indicator variables for the presence of each of the five categories of NTMs that are populated in the TRAINS database for the US as an importer. These are: (A) "sanitary and phytosanitary measures," (B) "technical barriers to trade," (C) "pre-shipment inspection and other formalities," (E) "non-automatic import licensing, quotas, prohibitions, quantity-control measures and other restrictions not including sanitary and phytosanitary measures or measures relating to technical barriers of trade", and (F) "price-control measures, including additional taxes and charges." In addition, we include a sixth indicator for the presence, according to the TTB database, of an active US antidumping or countervailing duty levied against any (ten-digit or eight-digit) product within the (six-digit) product g and origin i in 2017.

[37]Interestingly, the coefficient on NTM of type (F) "price-control measures, including additional taxes and charges" is negative, statistically different from zero, and an order of magnitude larger than other NTM dummies, consistent with the idea that NTM of type (F) are associated with fiscal externalities.

[38]We have also considered an alternative regression with dummies for PTA countries, GSP countries, and non-WTO countries. Both the coefficients on PTA and GSP countries are negative and statistically significant, consistent with the US implicitly putting higher welfare weight on these groups of countries. The coefficient on the non-WTO dummy is negative as well but very imprecise, due to the small number of non-WTO countries in our sample.

multaneity bias of this form has been stressed in prior work. The predominant solution seeks to construct an IV for the dependent variable that predicts trade due to forces other than trade policy. A natural candidate, in our context, is our model's predicted value of the regressors $\partial(\omega_j - \bar{\omega})/\partial m_{ig}$, but constructed from a counterfactual economy with zero tariffs. Namely, we predict the impact of imports on real earnings on the basis of technology- and endowment-based forces, rather than policy, in the same spirit as Trefler (1993) and Goldberg and Maggi (1999). As seen in Figure 6d, our IV and OLS estimates are extremely similar to one another (correlation of 0.95, slope of 0.77), indicating that any bias caused by simultaneity is relatively weak.

A generic concern associated with a revealed-preference approach such as ours is that the variation in observed choices, here US tariffs, may reflect constraints on the decision-marker choice sets rather than variation in the underlying preferences. Our baseline analysis assumes away such constraints, implicitly treating the decision of the US to abide by WTO rules or enter a preferential trade agreement as choices that reveal social preferences. Alternatively, one may view the latter as constraints that predate the choices of 2017 US tariffs that we analyze (e.g. the last WTO-mandated multilateral trade agreement was signed in 1995) and should therefore be added to the list of constraints entering the planner's problem in Definition 2. In turn, our general tariff formula should only be applied to the subset of goods whose imports remain under the control of the government. A simple way to assess the importance of such constraints is to re-estimate $\hat{\beta}_s$ and $\hat{\beta}_r$ while omitting foreign countries i and products g if country i is a WTO member and the US tariff is at its WTO bound for good g (i.e., there is no "overhang" for that product) or if the country-product pair (i, g) is covered by a preferential trade agreement. While such a subsample comprises only 4.0% of our baseline sample, we still see (in Figure 6e) a high correlation (of 0.96) between the estimates from such sample and those from the full sample. This suggests that the constraint of prior trade agreements does not appear to bind in a way that dramatically affects the way that the US can use its trade policy to achieve its redistributional goals.

Figure 6f explores the related issue of how MFN may constrain US trade policy, and hence should be accounted for when inferring social preferences. For any product g imported from a WTO member i, the US is supposed to impose a common tariff t_g. When such constraint is imposed, our general tariff formula should now apply when expressed in terms of total imports from WTO countries, as established in equation (A.3). Yet even when estimating equation (24) on origins i that are WTO members, and using as our adjusted formula to account for MFN, we find remarkably similar estimates. Again, this suggests that WTO rules are unobtrusive as concerns domestic redistribution.[39]

As final robustness exercise we explore the relevance of demographic groups in determining US trade policy. To do so, we augment our baseline model of welfare weights $\beta(h)$—that such weights comprise additive components β_r and β_s reflecting household h's region of residence and sector of employment—to include a third additive effect β_d for the demographic groups to which the household belongs. In particular, we allow for groups based on binary categories of education (college-educated and not), gender, and race (white and non-white). Appendix Figure D.7a demonstrates that the estimates of $\hat{\beta}_r$ and $\hat{\beta}_s$ obtained when allowing for demographic considerations are remarkably unchanged.[40]

5 The Incidence of Redistributive Protection

5.1 How Large are the Transfers Caused by Redistributive Protection?

The results in Section 4 have demonstrated a substantial role for redistributive motives in US trade policy in the sense that such motives can account for a large share of the cross-sectional variation in US tariffs. But from an economic rather than statistical standpoint, how important are redistributive tariffs? That is, how large are the monetary transfers experienced by winners and losers from redistributive trade protection?

To answer this question we return to the quantitative model from Section 3 to construct a counterfactual US economy with trade taxes equal to

$$t'_{ig} = t_{ig} + \sum_{s \in \mathcal{S}} \hat{\beta}_s H_s \frac{\partial(\omega_s - \bar{\omega})}{\partial m_{ig}} + \sum_{r \in \mathcal{R}_H} \hat{\beta}_r H_r \frac{\partial(\omega_r - \bar{\omega})}{\partial m_{ig}}. \tag{25}$$

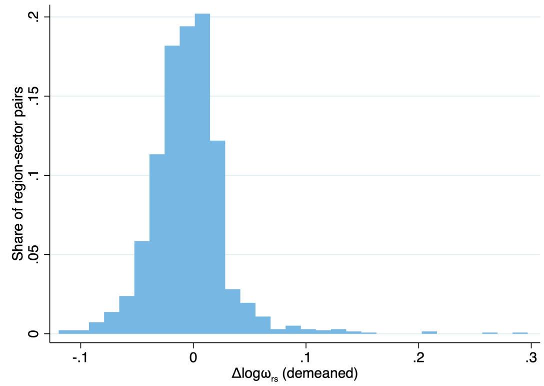
In words, this counterfactual scenario removes from the observed US tariff t_{ig} the redistributive component estimated in Section 4. Doing so is equivalent to considering a counterfactual US economy in which social marginal returns to different households have been equalized, perhaps due to the availability of lump-sum transfers, holding fixed the other motives for trade protection.[41] We then calculate the changes in real income of all

[39] For the interested reader, Appendix Table D.1 further documents that are our estimates of $\hat{\beta}_r$ and $\hat{\beta}_s$ are robust to dropping the intercept and the terms-of-trade motive from our set of controls.

[40] Appendix Figure D.7b also reports the composition-adjusted estimates of β_d themselves.

[41] In theory, both the terms-of-trade motive and the distortions motive may further change in this counterfactual scenario. Given the small coefficient that we have estimated in front the terms-of-trade control $m \cdot (\partial p^w / \partial m_{ig})$ in Section 4, taking into account the former effect using the structure of our quantitative model has very little effect on our analysis. Since we have not made any assumption on the structure of externalities $E(z)$ that enter the distortions motive and lack systematic empirical evidence on $\epsilon \cdot (\partial z / \partial m_{ig})$,

Figure 7: Incidence of redistributive tariffs



Notes: This figure reports the distribution of effects on real earnings, across US households, that result from a counterfacual US economy in which US tariffs are taken from their factual 2017 values to the value that would obtain in the absence of redistributional motives.

households in the economy. The magnitude of such changes puts a monetary value on the effective transfers (positive or negative) that each household was receiving, by way of the structure of protectionism, as a result of the actual 2017 tariffs.

Figure 7 displays the density plot of the resulting counterfactual changes in real earnings ω_{rs} across all $|\mathcal{S}| \times |\mathcal{R}_H|$ sector-region combinations. As expected, there is a dispersion of effects, with households from some sector-regions seeing their real income rise and others seeing a fall. These changes in real incomes that result from removing the redistributive motive of trade policy can be interpreted as the as-if transfer that each household must pay or benefits from as a result of the 2017 policy. Evidently, some households pay and receive economically meaningful transfers. For example, the 90-10 difference across households runs from a gain of $2,185 per worker, per annum to a loss of $7,275 per worker, per annum

5.2 Who Wins and Who Loses from Redistributive Protection?

Up to this point, we have remained agnostic about the specific dimensions of the US political process that may be driving redistributive tariffs. All that matters for our estimates of the welfare weights β_s and β_r as well as the associated incidence of redistributive tariffs is that this process arrives at some Pareto-efficient outcome. To conclude our analysis, we return to two leading explanations for the existence of tariffs in the previous political-economy literature, namely sectors' ability to lobby and state's ability to "swing" presidential elections, and use our previous estimates to evaluate the gains from redistributive

we view our "no change" assumption as a useful starting point.

trade protection associated with these two sector- and region-characteristics.

For this final exercise, we divide sectors of employment as either "high-" or "low-trade lobbying" based on LobbyView data that allow us to compute total lobbying spending on filings that cite trade policy as their primary purpose.[42] Likewise, we divide US regions into "swing states" and "non-swing states," with the former group defined as the six states (Arizona, Florida, Iowa, North Carolina, Ohio, and Virginia) with the closest average vote margin in presidential elections between 2000 and 2016.

Our results are presented in Figure 8. As one might expect, both households employed in sectors with high levels of lobbying expenditure per worker and those living in swing states tend to gain more from redistributive protection. Perhaps more surprising, though consistent with our earlier variance decomposition highlighting the importance of sector-relative to region-based characteristics, the impact of lobbying is an order of magnitude more important than the impact of being in a swing state.[43] According to our estimates, workers employed in high-trade lobbying sectors, which spend around $46 per worker on lobbying, end up receiving the equivalent of $3,100 via redistributive trade protection.

6 Concluding Remarks

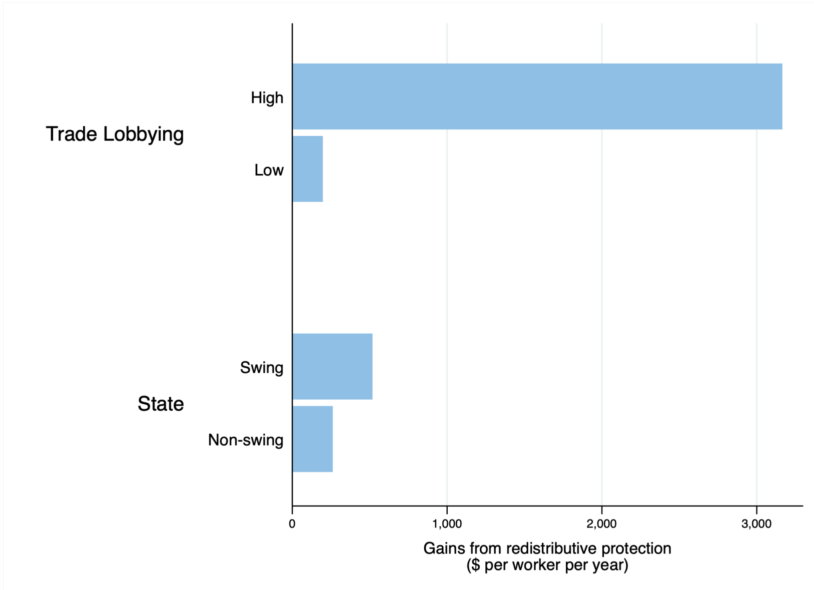
We live in an age of rising protectionism that is unprecedented in the post-WWII era. Why is free trade in shackles? A prominent starting point in the literature that provides answers to this question focuses on ways that trade protection may be used as a way to achieve distributional objectives across groups of society. The goal of this paper has been to develop methods that can be used to evaluate the extent of redistributive protectionism.

Our general tariff formula emerges from any Pareto efficient political process. It highlights a simple sense in which the distributional motives behind the tariff observed on any good should reflect a combination of groups' "as-if" Pareto weights and the marginal impact that importing more of that good would have on the real income of the groups' members. Inverting this logic, and armed with an empirical economic model of how

[42] In particular, we calculate total lobbying expenditures during 2011-2015, among firms in each sector, on the basis of filing reports that list international trade as the primary purpose of the contract. We then divide this value by the employment share of the sector and classify sectors into "high" and "low" lobbying categories by using a k-means clustering procedure (with k=2) based on the log of lobbying spending per worker. The sectors in the "high" group are: Apparel, Chemical products, Computer and electronic products, Electrical equipment, Mining (except oil and gas), Nonmetallic mineral products, Petroleum and coal products, Plastics and rubber products, Primary metals, and Wholesale trade.

[43] Appendix Figure D.8 reports the analog of Figure 8 for sectors grouped on the basis of lobbying spending for all purposes. As expected, these display a considerably weaker relationship with our estimated gains from redistributive protection.

Figure 8: Lobbying, Swing States, and Gains from Redistributive Protection



Notes: This figure plots the gains from redistributive protection, defined as minus the real income loss of going from the factual 2017 values of the US tariffs to their counterfactual values in the absence of redistributional motives, for different groups of US households.

marginal imports affect households' welfare differentially, a simple regression-based procedure can recover the "revealed" Pareto weights that can locate the point on society's Pareto frontier that political processes arrive at.

When applied to U.S. trade policy in 2017 we find that redistribution across 51 regions and 29 sectors explains almost one third of the variance in US tariffs observed across thousands of products and origin countries. Perhaps surprisingly, the redistributive motive that we estimate is considerably stronger for cross-sectoral considerations than cross-state considerations. Finally, we have evaluated the incidence of US redistributive tariffs on US households' real earnings. Our analysis highlights the large monetary transfers—approximately $10,000 per year per person when comparing the 90-10 gap in relative benefits—associated with redistributive trade protection.

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A Theoretical Appendix

A.1 Proof of Proposition 1

Proof. Start from the Lagrangian associated with the government's problem,

$$\mathcal{L} = u(c(h_0), z; h_0) + \sum_{h \neq h_0} \nu(h)[u(c(h), z; h) - \underline{u}(h)],$$

with $\nu(h) \geq 0$ the Lagrange multiplier associated with the utility constraint of household h. Consider a small change in Home's trade taxes, $dt \equiv \{dt_n\}_{n \in \mathcal{N}^T}$. Let $du(h)$ denotes the change in the utility of household h. If trade taxes are constrained Pareto efficient at $t = t^*$, the following necessary first-order condition must hold,

$$\sum_{h \in \mathcal{H}} \nu(h) du(h) = 0, \text{ for all } n \in \mathcal{N}_T, \tag{A.1}$$

where we use the convention $\nu(h_0) = 1$.

In a competitive equilibrium, utility maximization by household h, as described in (7), and the government's budget balance, as described in (9), imply

$$e(p, z, u(h); h) = \pi \cdot \theta(h) + \frac{1}{H}(t^* \cdot m).$$

Differentiating and invoking the Envelope Theorem, we can express the change in h's utility as

$$du(h) = \mu(h)\{\theta(h) \cdot d\pi - c(h) \cdot dp - e_z(h) \cdot dz + \frac{1}{H}[t^* \cdot dm + m \cdot (dp - dp^w)]\}. \tag{A.2}$$

where we have used $\mu(h) = 1/e_{u(h)}$, with $e_{u(h)} \equiv \partial e(p, z, u(h); h)/\partial u(h)$ and $e_z(h) \equiv \{\partial e(p, z, u(h); h)/\partial z_k\}$.

Next, consider profit maximization by firm f, as described in (6). By the same envelope argument, the change in firm f's profits satisfies

$$d\pi(f) = y(f) \cdot dp + \pi_z(f) \cdot dz,$$

with $\pi_z(f) \equiv \{\partial \pi(p, z; f)/\partial z_k\}$. Substituting into (A.2), we then obtain

$$du(h) = \mu(h)\{d\omega(h) + [\pi_z(h) - e_z(h)] \cdot dz + \frac{1}{H}[t^* \cdot dm + m \cdot (dp - dp^w)]\},$$

with $d\omega(h) \equiv [y(h) - c(h)] \cdot dp$, $y(h) \equiv \{\sum_{f \in \mathcal{F}} y_n(f)\theta(f,h)\}$, and $\pi_z(h) \equiv \{\sum_{f \in \mathcal{F}} \theta(f,h)\pi_z(f)\}$.

From the good market clearing condition (8), we know that $m = \sum_{h \in \mathcal{H}} c(h) - \sum_{f \in \mathcal{F}} y(f)$. Since $\sum_{h \in \mathcal{H}} \theta(f,h) = 1$, it follows that $m \cdot dp = -\sum_{h \in \mathcal{H}} d\omega(h)$ and, in turn, that

$$du(h) = \mu(h)\{d\omega(h) - d\bar{\omega} + [\pi_z(h) - e_z(h)] \cdot dz + \frac{1}{H}[t^* \cdot dm - m \cdot dp^w]\},$$

with $d\bar{\omega} \equiv \sum_{h \in \mathcal{H}} d\omega(h)/H$. Substituting into (A.1) we get

$$t^* \cdot dm = -\beta \cdot d(\omega - \bar{\omega}) + m \cdot dp^w - \epsilon \cdot dz.$$

with $\beta(h) \equiv \lambda(h)/\bar{\lambda}$, $\beta \equiv \{\beta(h)\}$ and $\epsilon \equiv \sum_{h \in \mathcal{H}} \beta(h)[e_z(h) - \pi_z(h)]$.

Now for any $n \in \mathcal{N}_T$, consider dt such that $dt_n > 0$ and $dt_r = 0$ for any $r \neq n \in \mathcal{N}_T$. For the previous condition to hold for any such variation, we must have

$$t^* \cdot \frac{\partial \tilde{m}}{\partial t_n} = -\beta \cdot \frac{\partial(\tilde{\omega} - \tilde{\bar{\omega}})}{\partial t_n} + m \cdot \frac{\partial \tilde{p}^w}{\partial t_n} + \epsilon \cdot \frac{\partial \tilde{z}}{\partial t_n}, \text{ for all } n \in \mathcal{N}_{\mathcal{T}},$$

where tildes reflect the fact that all equilibrium variables are expressed as a function of t, including $\partial(\tilde{\omega} - \tilde{\bar{\omega}})/\partial t_n \equiv [y(h) - c(h)] \cdot [\partial \tilde{p}/\partial t_n]$. In matrix notation, this is equivalent to

$$(t^{*T})' D_t \tilde{m}^T = -\beta' D_t(\tilde{\omega} - \tilde{\bar{\omega}}) + m' D_t \tilde{p}^w + \epsilon' D_t \tilde{z}^w,$$

with $t^{*T} \equiv \{t_n^*\}_{n \in \mathcal{N}^T}$ the vector of potentially non-zero trade taxes and $m^T \equiv \{m_n\}_{n \in \mathcal{N}^T}$ the associated vector of imports.

Finally, multiply both sides by $(D_t \tilde{m}^T)^{-1}$ and use the fact that for any function $x(m^T) \equiv \tilde{x}(t^{-1}(m^T))$, $(D_{m^T} x) = (D_t \tilde{x})(D_t \tilde{m}^T)^{-1}$ to get

$$(t^{*T})' = -\beta' D_{m^T}(\omega - \bar{\omega}) + m' D_{m^T} p^w + \epsilon' D_{m^T} p^w.$$

Expressed good by good, this is equivalent to

$$t_n^* = -\beta \cdot \frac{\partial(\omega - \bar{\omega})}{\partial m_n} + m \cdot \frac{\partial p^w}{\partial m_n} + \epsilon \cdot \frac{\partial z}{\partial m_n} \text{ for all } n \in \mathcal{N}_T.$$

This concludes the proof of Proposition 1. □

A.2 Extensions of Proposition 1

Non-Tariff Barriers. Consider a generalized version of the environment of Section 2.1 in which, in addition, to trade taxes, Home's government may also choose non-tariff barriers $s \in \mathcal{S}$. This potentially high-dimensional vector captures all product standards, environmental regulations, labor standards etc. that the government may decide to impose on domestic firms, foreign firms, or both. Such non-tariff barriers may affect domestic firms' production sets, $Y(z, s; f)$; domestic households' utility $u(c(h), z, s; h)$; as well as Foreign's offer curve $\Omega(p^w, z, s)$. For any given non-tariff barriers $s \in \mathcal{S}$, the exact same arguments as in the proof of Proposition 1 continue to hold. Hence the optimal tariff formula in equation (10) remains unchanged.

Coarse Trade Taxes. Consider an alternative version of the environment of Section 2.1 in which trade taxes are constrained to take the same values among subsets of goods, for instance because the domestic government may not discriminate between different foreign origins. Formally, suppose that there is a partition of the set of goods $\{\mathcal{N}_g\}_{g \in \mathcal{G}} = \mathcal{N}^T$ such that $t_n = \hat{t}_g$ for all goods $n \in \mathcal{N}_g$. Except for the previous constraint, the government can freely choose the level of the tax t_g on each group of goods $g \in \mathcal{G}$. In this alternative environment, Proposition 1 extends as follows.

Proposition 1 (Coarse Trade Taxes)**.** *Suppose that for any group of goods $g \in \mathcal{G}$, trade taxes are constrained to take the same value for all goods $n \in \mathcal{N}_g$. Then constrained Pareto efficient trade taxes satisfy*

$$t_n^* = -\beta \cdot \frac{\partial(\omega - \bar{\omega})}{\partial M_g} + m \cdot \frac{\partial p^w}{\partial M_g} + \epsilon \cdot \frac{\partial z}{\partial M_g} \textit{ for all } n \in \mathcal{N}_g \textit{and } g \in \mathcal{G}, \tag{A.3}$$

with $M_g \equiv \sum_{n \in \mathcal{N}_g} m_n$ the total imports of goods from group g.

Proof. Let $\hat{t}^* \equiv \{\hat{t}_g^*\}_{g \in \mathcal{G}}$ denote the vector of trade taxes that the government can freel impose across different groups of goods $g \in \mathcal{G}$. The same arguments as in the proof of Proposition 1 now imply

$$(\hat{t}^*)' D_t \tilde{M} = -\beta' D_t(\tilde{\omega} - \tilde{\bar{\omega}}) + m' D_t \tilde{p}^w + \epsilon' D_t \tilde{z}^w,$$

with $\tilde{M} \equiv \{\tilde{M}_g\}_{g \in \mathcal{G}}$ the vector of imports associated with each group of good g, expressed as a function of the trade taxes imposed on each gorup $\hat{t}$. Multiplying both sides by $(D_t \tilde{M})^{-1}$, we obtain (A.3). □

Exogenous Trade Taxes. Consider a generalized version of the environment of Section 2.1 in which, in addition to the subset $\mathcal{N}^T$ of goods that can be taxed freely by Home's government, there exists another subset of goods $\bar{\mathcal{N}} = \mathcal{N} - \mathcal{N}^T$ that face exogenous trade taxes $\bar{t} \equiv \{\bar{t}_n\}_{n\in\bar{\mathcal{N}}}$, perhaps because of some prior trade agreements. The environment of Section 2.1 corresponds to the special case in which $\bar{t} = 0$. In this alternative environment, Proposition 1 extends as follows.

Proposition 1 (Exogenous Trade Taxes)**.** *Suppose that there exists a subset of goods $\bar{\mathcal{N}}$ facing exogenous trade taxes $\bar{t}$. Then constrained Pareto efficient trade taxes satisfy*

$$t_n^* = -\beta \cdot \frac{\partial(\omega - \bar{\omega})}{\partial m_n} + m \cdot \frac{\partial p^w}{\partial m_n} + \epsilon \cdot \frac{\partial z}{\partial m_n} - \bar{t} \cdot \frac{\partial \bar{m}}{\partial m_n} \text{ for all } n \in \mathcal{N}^T, \tag{A.4}$$

with $\bar{m} \equiv \{m_n\}_{n\in\bar{\mathcal{N}}}$ the vector of imports associated with exogenous trade taxes.

Proof. Like in the proof of Proposition (1), let $t^{*T} \equiv \{t_n^*\}_{n\in\mathcal{N}^T}$ denote the optimal vector of trade taxes that can be freely chosen by the government. The same arguments as in the proof of Proposition 1 now imply

$$(t^{*T})' D_t \tilde{m}^T + (\bar{t})' D_t \tilde{\bar{m}} = -\beta' D_t(\tilde{\omega} - \tilde{\bar{\omega}}) + m' D_t \tilde{p}^w + \epsilon' D_t \tilde{z}^w,$$

with $\tilde{\bar{m}} \equiv \{\tilde{m}_n\}_{n\in\bar{\mathcal{N}}}$ the vector of imports associated with constrained trade taxes, expressed as a function of the unconstrained trade taxes $t \in \mathcal{T}$. Multiplying both sides by $(D_t \tilde{m}^T)^{-1}$, we obtain (A.4). □

Other Taxes. Consider a generalized version of the environment of Section 2.1 in which, in addition to trade taxes, the government may now impose producer taxes $t^y \equiv \{t_n^y\}$ that create a wedge between the prices p faced between domestic households and the prices q faced by domestic firms,

$$q_n = p_n + t_n^y. \tag{A.5}$$

Hence, the profit maximization problem of a given firm f is

$$\max_{y\in Y(z;f)} q \cdot y, \tag{A.6}$$

and the budget constraint of the domestic government is

$$t \cdot m + t^y \cdot y^{\text{total}} = H\tau,$$

where $y^{\text{total}} \equiv \{\sum_{f\in\mathcal{F}} y_n(f)\}$ denotes the total output of domestic firms. All other equilibrium conditions are unchanged. Proposition 1 then extends as follows.

Proposition 1 (Producer Taxes)**.** *Suppose that domestic firms face producer taxes t^y. Then constrained Pareto efficient trade taxes satisfy*

$$t_n^* = (1-\beta)\cdot\frac{\partial\omega}{\partial m_n} + m\cdot\frac{\partial p^w}{\partial m_n} + \epsilon\cdot\frac{\partial z}{\partial m_n} - t^y\cdot\frac{\partial y^{total}}{\partial m_n} \textit{ for all } n\in\mathcal{N}^T, \tag{A.7}$$

with $y^{total} \equiv \{\sum_{f\in\mathcal{F}} y_n(f)\}$ the total output of domestic firms.

Proof. Given (A.5) and (A.6), the same arguments as in the proof of Proposition 1 imply

$$(t^{*T})'D_t\tilde{m}^T + (t^y)'D_t\tilde{y}^{\text{total}} = -\beta' D_t(\tilde{\omega} - \tilde{\bar{\omega}}) + m'D_t\tilde{p}^w + \epsilon' D_t\tilde{z}^w,$$

with $\tilde{y}^{\text{total}} \equiv \{\sum_{f\in\mathcal{F}} \tilde{y}_n(f)\}$ the total output of domestic firms, expressed as a function of $t\in\mathcal{T}$. Multiplying both sides by $(D_t\tilde{m}^T)^{-1}$, we obtain (A.7). □

Trade Talks. Consider a variation of the environment of Section 2.1 in which Foreign's offer curve in (4) derives from the existence of a representative agent abroad choosing the vector of Home's imports m in order to solve

$$\begin{aligned}&\max_m u_F(-m) \\ &\text{subject to:} p^w\cdot m = 0.\end{aligned} \tag{A.8}$$

That is, $m\in\Omega(p^w, z)$ if and only if m solves (A.8).[44] Suppose in addition that Pareto efficient trade taxes at Home now solve

$$\begin{aligned}&\max_{t\in\mathcal{T}} u(c(h_0), z; h_0) \\ &\text{subject to: } u(c(h), z; h) \geq \underline{u}(h) \text{ for } h\neq h_0, \\ &u_F(m) \geq \underline{u}_F, \\ &(\{c(h)\}, m, z)\in\tilde{\mathcal{E}}(t),\end{aligned} \tag{A.9}$$

[44] As is well-known, (A.8) holds if there exist a representative agent abroad who chooses c_F to maximize her utility taking prices p^w as given, perfectly competitive firms abroad that choose y_F to maximize their profits, and Home's net imports are equal to $m = y_F - c_F$. The maximand $u_F(-m)$ is what Dixit and Norman (1980) refer to as the "Meade utility function."

where $\tilde{\mathcal{E}}(t)$ denotes the set of domestic consumption, net imports, and externalities vectors attainable in a competitive equilibrium with trade taxes t.

In this alternative environment, Proposition 1 extends as follows.

Proposition 1 (Trade Talks)**.** *Suppose that there is a representative agent abroad whose utility the domestic government cares about. Then constrained Pareto efficient trade taxes satisfy*

$$t_n^* = -\beta \cdot \frac{\partial(\omega - \bar{\omega})}{\partial m_n} + (1 - \beta_F)\left(m \cdot \frac{\partial p^w}{\partial m_n}\right) + \epsilon \cdot \frac{\partial z}{\partial m_n} \text{ for all } n \in \mathcal{N}^T, \tag{A.10}$$

with $\beta_F \equiv \lambda_F / \bar{\lambda}$ and λ_F the social marginal utility of foreign income (from Home's perspective).

Proof. The Lagrangian associated with (A.9) is

$$\mathcal{L} = u(c(h_0), z; h_0) + \sum_{h \neq h_0} \nu(h)[u(c(h), z; h) - \underline{u}(h)] + \nu_F[u_F(m) - \underline{u}_F],$$

with $\nu_F \geq 0$ the Lagrange multiplier associated with the utility constraint of the foreign representative agent. The first-order condition (A.1) in the proof of Proposition 1 therefore generalizes to

$$\sum_{h \in \mathcal{H}} \nu(h) du(h) + \nu_F du_F(m) = 0, \text{ for all } n \in \mathcal{N}_T. \tag{A.11}$$

Starting from (A.8) and invoking the Envelope Theorem, we get

$$du_F = \mu_F(m \cdot dp^w), \tag{A.12}$$

with $\mu_F \geq 0$ the Lagrange multiplier associated with the foreign representative agent's budget constraint in (A.8). Starting from (A.11) and (A.12) and following the same steps as in the proof of Proposition 1, we then obtain (A.10), with $\lambda_F \equiv \mu_F \nu_F \geq 0$ the social marginal utility of foreign income (from Home's perspective). □

Other Distortions. Consider a variation of the environment of Section 2.1 with imperfect competition, as modeled in Costinot and Werning (2019). Instead of (6), each domestic firm $f \in \mathcal{F}$ chooses a correspondence $\sigma(f) \in \Sigma(f)$ that describes the set of quantities $y(f)$ that it is willing to supply and demand at every domestic price vector p. The feasible set $\Sigma(f)$ reflects both technological constraints and the strategic nature of competition. It may restrict a firm to choose a vertical schedule, i.e., fixed quantities, as under Cournot competition, or a horizontal schedule, i.e., fixed prices, as under Bertrand competition.

For each strategy profile $\sigma \equiv \{\sigma(f)\}$, an auctioneer then selects domestic and foreign prices $(P(\sigma), P^w(\sigma))$, a vector of net imports $M(\sigma)$, a vector of externalities $Z(\sigma)$, a domestic allocation $\{Y(\sigma, f), C(\sigma, h)\}$ and a transfer $\tau(\sigma)$ such that the equilibrium conditions (i), (ii), (iii), (v), (vi), and (vii) in Definition 1 hold. Firm f solves

$$\max_{\sigma(f)\in\Sigma(f)} P(\sigma) \cdot Y(\sigma, f), \tag{A.13}$$

taking the correspondences of other firms $\{\sigma(f')\}_{f' \neq f}$ as given.

In this alternative environment, Proposition 1 extends as follows.

Proposition 1 (Imperfect Competition)**.** *Suppose that firms are imperfectly competitive. Then constrained Pareto efficient trade taxes satisfy*

$$t_n^* = -\beta \cdot \frac{\partial(\omega - \bar{\omega})}{\partial m_n} + m \cdot \frac{\partial p^w}{\partial m_n} + \epsilon \cdot \frac{\partial z}{\partial m_n} - \sum_{f\in\mathcal{F}} \epsilon^y(f) \cdot \frac{\partial y(f)}{\partial m_n} \text{ for all } n \in \mathcal{N}^T, \tag{A.14}$$

with $\epsilon^z \equiv \sum_{h\in\mathcal{H}} \beta(h) e_z(h)$ the social marginal cost of externalities and $\epsilon^y(f) \equiv [\sum_{h\in\mathcal{H}} \beta(h)\theta(f,h)]p$ the social marginal costs of distortions in firm f's output.

Proof. Compared to the proof of Proposition 1, equations (A.1) and (A.2) continue to hold, but (**??**) becomes

$$d\pi(f) = y(f) \cdot dp + p \cdot dy(f), \tag{A.15}$$

with $\pi(f)$ the equilibrium profits of firm f. Substituting (A.15) into (A.2), we then obtain

$$du(h) = \mu(h)\{d\omega(h) + \sum_{f\in\mathcal{F}} \theta(f,h)[p \cdot dy(f)] - e_z(h) \cdot dz + \frac{1}{H}[t^* \cdot dm + m \cdot (dp - dp^w)]\}.$$

The same arguments as in the proof of Proposition 1 then implies (A.14). □

B Quantitative Model

This section describes how we compute the competitive equilibrium of the quantitative model introduced in Sections 3 and 3.2.

B.1 Competitive Equilibrium

B.1.1 Prices

For each origin region or country $o \in \mathcal{R}$, destination $d \in \mathcal{R}$, and product $g \in \mathcal{G}_s$ from sector $s \in \mathcal{S}$, we denote by p_{odg} this good's domestic price. Equations (12)-(15) then imply that for all $r \in \mathcal{R}_{\mathcal{H}}$, destination $d \in \mathcal{R}$, and product $g \in \mathcal{G}_s$ from sector $s \in \mathcal{S}$,

$$p_{rdg} = (\theta_{rds})^{-1}[\alpha_s]^{-\alpha_s} \prod_{k \in S} [\alpha_{ks}]^{-\alpha_{ks}} [P_{rk}]^{\alpha_{ks}}, \tag{B.1}$$

$$\text{where} \quad P_{rk} \equiv \left[\sum_{c=H,F} \theta^c_{rk} [P^c_{rk}]^{1-\kappa} \right]^{\frac{1}{1-\kappa}},$$

$$P^c_{rk} \equiv \left[\sum_{v \in \mathcal{G}_k} \theta^c_{rkv} [P^c_{rkv}]^{1-\eta} \right]^{\frac{1}{1-\eta}},$$

$$P^c_{rkv} \equiv \left[\sum_{o \in \mathcal{R}_c} \theta^c_{orkv} [p_{orv}]^{1-\sigma} \right]^{\frac{1}{1-\sigma}}.$$

Note that this expression implies p_{rdg} is constant across products $g \in \mathcal{G}_s$ within the same sector $s \in \mathcal{S}$; we denote this common price by p_{rds} for all $r \in \mathcal{R}_H$, $d \in \mathcal{R}$, and $s \in \mathcal{S}$. Our assumptions that $\theta^H_{rkv} = \bar{\theta}^H_{rk} = 1/|\mathcal{G}_k|$and $\theta^H_{orkv} = \bar{\theta}^H_{ork}$ then imply that for all $r \in \mathcal{R}_H$, $k \in \mathcal{S}$,

$$P^H_{rk} = \left[\sum_{o \in \mathcal{R}_H} \bar{\theta}^H_{ork} [p_{ork}]^{1-\sigma} \right]^{\frac{1}{1-\sigma}}.$$

Finally, note that for all $r \in \mathcal{R}_H$, and $s \in \mathcal{S}$, the price p_{rds} differs across destinations $d \in \mathcal{R}$ proportionally to $(\theta_{rds})^{-1}$. We let p_{rs} denote the common, productivity-adjusted price equal to $\theta_{rds} p_{rdg}$for every $d \in \mathcal{R}$.

Combining the observations above, we express the equilibrium conditions simply in terms of the region-sector-level prices p_{rs}: For all $r \in \mathcal{R}_{\mathcal{H}}$, destination $d \in \mathcal{R}$, and sector

$s \in \mathcal{S}$, the price p_{rdg} of every product $g \in \mathcal{G}_s$ in sector $s \in \mathcal{S}$ is equal to

$$p_{rs} = [\alpha_s]^{-\alpha_s} \prod_{k \in S} [\alpha_{ks}]^{-\alpha_{ks}} [P_{rk}]^{\alpha_{ks}}, \tag{B.2}$$

$$\text{where} \quad P_{rk} \equiv \left[\sum_{c=H,F} \theta^c_{rk} [P^c_{rk}]^{1-\kappa} \right]^{\frac{1}{1-\kappa}}, \tag{B.3}$$

$$P^H_{rk} = \left[\sum_{o \in \mathcal{R}_H} \tilde{\theta}^H_{ork} [p_{ok}]^{1-\sigma} \right]^{\frac{1}{1-\sigma}}, \tag{B.4}$$

$$P^F_{rk} \equiv \left[\sum_{v \in \mathcal{G}_k} \theta^F_{rkv} [P^F_{rkv}]^{1-\eta} \right]^{\frac{1}{1-\eta}}, \tag{B.5}$$

$$P^F_{rkv} \equiv \left[\sum_{o \in \mathcal{R}_F} \theta^F_{orkv} [p_{orv}]^{1-\sigma} \right]^{\frac{1}{1-\sigma}}, \tag{B.6}$$

where $\tilde{\theta}^H_{ork} \equiv \bar{\theta}^H_{ork} / (\theta_{ork})^{1-\sigma}$.

B.1.2 Bilateral Trade Flows

The expressions for prices in equations (B.2)-(B.6) and the expressions for technology and preferences in equations (12)-(15) and (16)-(19) imply that input expenditures in domestic region $r \in \mathcal{R}_H$ on product $g \in \mathcal{G}_s$ of sector $s \in \mathcal{S}$ from foreign country $i \in \mathcal{R}_F$ are given by

$$X^M_{irsg} = \frac{\theta^F_{irsg} [p_{irg}]^{1-\sigma}}{[P^F_{rsg}]^{1-\sigma}} X^M_{rsg}, \tag{B.7}$$

$$\text{where} \quad X^M_{rsg} \equiv \frac{\theta^F_{rsg} [P^F_{rsg}]^{1-\eta}}{[P^F_{rs}]^{1-\eta}} X^M_{rs},$$

$$X^M_{rs} \equiv \frac{\theta^F_{rs} [P^F_{rs}]^{1-\kappa}}{[P_{rs}]^{1-\kappa}} X_{rs},$$

where X_{rs} is total, sector-s expenditures by consumers and firms in region r. Similarly, input expenditures in region r on all products in sector $s \in \mathcal{S}$ from domestic region $i \in$

$\mathcal{R}_H$ are given by

$$X_{irs}^H = \frac{\tilde{\theta}_{irs}^H [p_{is}]^{1-\sigma}}{[P_{rs}^H]^{1-\sigma}} X_{rs}^H, \tag{B.8}$$
$$\text{where} \quad X_{rs}^H \equiv \frac{\theta_{rs}^H [P_{rs}^H]^{1-\kappa}}{[P_{rs}]^{1-\kappa}} X_{rs}.$$

Producer's problem. Equation (12) and the above definition of $P_{j,s}$ imply that problem of the representative producer f that produces a product $g \in \mathcal{G}_s$ within a sector $s \in \mathcal{S}$ in region $r \in \mathcal{R}_H$ for use in region $d \in \mathcal{R}$ is

$$\max_{\ell_{rs}(f),\, Q_{rk}(f)} p_{rdg}\theta_{rds}(\ell_{r,s}(f))^{\alpha_s} \prod_k (Q_{rk}(f))^{\alpha_{ks}} - w_{rs}\ell_{rs}(f) - \sum_k P_{rk}Q_{rk}(f).$$

This implies

$$w_{rs}\ell_{rs}(f) = \alpha_s Y_{rdg},$$
$$P_{rk}Q_{rk}(f) = \alpha_{ks} Y_{rdg},$$

where $Y_{rdg} = p_{rdg}q(f)$ is the firm's total revenue.

Aggregating across all firms within the same region $r \in \mathcal{R}_H$ and sector $s \in \mathcal{S}$ and applying the labor market clearing condition then implies

$$W_{rs} = \alpha_s Y_{rs}, \tag{B.9}$$
$$Z_{rks} = \alpha_{ks} Y_{rs},$$

where $W_{rs} \equiv w_{rs}H_{rs}$ and $Y_{rs} \equiv \sum_{d \in \mathcal{R}, g \in \mathcal{G}_s} Y_{rdg}$ are the total value added (also the wage bill) and revenue of all firms in domestic region r and sector s, and where Z_{rks} is the total expenditure of all such firms on intermediate inputs from sector k.

Alternatively, substituting in for $Q_{rk}(f)$ in each firm's production function and then aggregating to the state-sector level, we obtain

$$Y_{rs} = H_{rs}(p_{rd})^{1/\alpha_s} \prod_{k \in \mathcal{S}} [\alpha_{ks}/P_{rk}]^{\alpha_{ks}/\alpha_s}. \tag{B.10}$$

Final demand. Equation (16) implies that final demand expenditure in region r on sector s follows

$$F_{rs} = P_{rs}C_{rs} = \gamma_s I_r, \tag{B.11}$$

where I_r denotes total income in r, i.e.

$$I_r = \sum_{s\in\mathcal{S}} W_{rs} + \sum_{s\in\mathcal{S}} H_{rs}\tau,$$

with

$$\tau = \frac{1}{H}\sum_{i\in\mathcal{R}_F}\sum_{r\in\mathcal{R}_H}\sum_{s\in\mathcal{S}}\sum_{g\in\mathcal{G}_s}\frac{t_{ig}^{\text{ad-valorem}}}{1+t_{ig}^{\text{ad-valorem}}}X_{irsg}^{M}.$$

Finally, the consumption price index is given by

$$P_r^C = \prod_{k\in\mathcal{S}}(P_{r,k})^{\gamma_k}. \tag{B.12}$$

Market clearing Total spending of each region r on sector s is

$$X_{rs} = \bar{X}_{rs} + \gamma_s\left(\sum_{k\in\mathcal{S}}\alpha_k Y_{rk} + H_r\tau\right) + \sum_{k\in\mathcal{S}}\alpha_{sk}Y_{rk}, \tag{B.13}$$

where $H_r \equiv \sum_s H_{rs}$. Total domestic demand for sector s produced by region i is

$$X_{is}^H = \sum_{r\in\mathcal{R}_H} X_{irs}^H. \tag{B.14}$$

And, using equation (21) and the fact that Home has no export taxes, foreign country i's expenditure $X_{ris}^F = \sum_{g\in\mathcal{G}_s} p_{rig}^M x_{rig}$ on goods produced by domestic region r in sector s is

$$X_{ris}^F = (p_{rs})^{1-1/\omega_{M,F}}(\theta_{ris})^{-(1-1/\omega_{M,F})}\sum_{g\in\mathcal{G}_s}(\theta_{rig}^{M,F})^{1/\omega_{M,F}}.$$

Thus total foreign demand faced by region r in sector s, $X_{rs}^F \equiv \sum_i X_{ris}^F$, is given by

$$X_{rs}^F = \delta_{rs}(p_{rs})^{1-1/\omega_{M,F}}, \tag{B.15}$$

where

$$\delta_{rs} \equiv \sum_{i\in\mathcal{R}_F}(\theta_{ris})^{-(1-1/\omega_{M,F})}\sum_{g\in\mathcal{G}_s}(\theta_{rig}^{M,F})^{1/\omega_{M,F}}.$$

Domestic good market clearing then requires, for each region r and sector s,

$$Y_{rs} = X_{rs}^F + X_{rs}^H. \tag{B.16}$$

Finally, by equation (20), market clearing for imports requires that for all $i \in \mathcal{R}_F, r \in \mathcal{R}_r$, and $g \in \mathcal{G}$,

$$p_{irg} = \left[\theta_{irg}^{X,F}(1 + t_{ig}^{\text{ad-valorem}})\right]^{\frac{1}{1+\omega_{X,F}}} (X_{irsg}^M)^{\frac{\omega_{X,F}}{1+\omega_{X,F}}},$$

with X_{irg}^M given by equation (B.7).

B.2 Solving for Domestic Demand

A key step in our algorithm is to solve for domestic demands X_{rs} as a function of p_{is} and P_{rs}^M. This is a fixed point problem because spending (non-linearly) affects tariff revenue, which in turn affects spending.

We begin by characterizing tariff revenue as a function of p_{is} and P_{rs}^M and X_{rs}. From the expressions in Section B.1, we get that

$$X_{irsg}^M = \frac{\theta_{irsg}^F [p_{irg}]^{1-\sigma}}{[P_{rsg}^F]^{1-\sigma}} X_{rsg}^M,$$

$$p_{irg} = \left[\theta_{irg}^{X,F}(1 + t_{ig}^{\text{ad-valorem}})\right]^{\frac{1}{1+\omega_{X,F}}} (X_{irsg}^M)^{\frac{\omega_{X,F}}{1+\omega_{X,F}}}. \tag{B.17}$$

Thus,

$$p_{irg} = \left[\theta_{irg}^{X,F}(1 + t_{ig}^{\text{ad-valorem}})\right]^{\frac{1}{1+\omega_{X,F}\sigma}} (\theta_{irsg}^F)^{\frac{\omega_{X,F}}{1+\omega_{X,F}\sigma}} \left(\frac{X_{rsg}^M}{[P_{rsg}^F]^{1-\sigma}}\right)^{\frac{\omega_{X,F}}{1+\omega_{X,F}\sigma}},$$

$$X_{irsg}^M = \left[\theta_{irg}^{X,F}(1 + t_{ig}^{\text{ad-valorem}})\right]^{\frac{1-\sigma}{1+\omega_{X,F}\sigma}} (\theta_{irsg}^F)^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\sigma}} \left(\frac{X_{rsg}^M}{[P_{rsg}^F]^{1-\sigma}}\right)^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\sigma}}. \tag{B.18}$$

Let us write

$$X_{irsg}^M = \varphi_{irsg} \left(\frac{X_{rsg}^M}{[P_{rsg}^F]^{1-\sigma}}\right)^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\sigma}},$$

$$\text{where} \quad \varphi_{irsg} = \left[\theta_{irg}^{X,F}(1 + t_{ig}^{\text{ad-valorem}})\right]^{\frac{1-\sigma}{1+\omega_{X,F}\sigma}} (\theta_{irsg}^F)^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\sigma}}.$$

Since $(P_{rsg}^F)^{1-\sigma} = \sum_{i \in \mathcal{R}_F} \theta_{irsg}^F [p_{irg}]^{1-\sigma}$,

$$P_{rsg}^F = (X_{rsg}^M)^{\frac{\omega_{X,F}}{1+\omega_{X,F}}} \left[\sum_{i \in \mathcal{R}_F} \varphi_{irsg}\right]^{\frac{1+\omega_{X,F}\sigma}{(1+\omega_{X,F})(1-\sigma)}}.$$

Thus,

$$X^M_{irsg} = \frac{\varphi_{irsg}}{\sum_{o\in\mathcal{R}_F}\varphi_{orsg}} X^M_{rsg}.$$

Recall that $X^M_{rsg} = \frac{\theta^F_{rsg}[P^F_{rsg}]^{1-\eta}}{[P^F_{rs}]^{1-\eta}} X^M_{rs}$. So,

$$X^M_{rsg} = (\theta^F_{rsg})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\eta}} \left[\sum_{i\in\mathcal{R}_F}\varphi_{irsg}\right]^{\frac{(1+\omega_{X,F}\sigma)(1-\eta)}{(1+\omega_{X,F}\eta)(1-\sigma)}} \left[\frac{X^M_{rs}}{[P^F_{rs}]^{1-\eta}}\right]^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\eta}}.$$

Since $[P^F_{rs}]^{1-\eta} = \sum_{g\in\mathcal{G}_s}\theta^F_{rsg}[P^F_{rsg}]^{1-\eta}$,

$$P^F_{rs} = \left[X^M_{rs}\right]^{\frac{\omega_{X,F}}{1+\omega_{X,F}}} [\mu_{rs}]^{\frac{1+\omega_{X,F}\eta}{(1+\omega_{X,F})(1-\eta)}},$$

$$\text{where} \quad \mu_{rs} = \sum_{g\in\mathcal{G}_s}(\theta^F_{rsg})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\eta}} \left[\sum_{i\in\mathcal{R}_F}\varphi_{irsg}\right]^{\frac{(1+\omega_{X,F}\sigma)(1-\eta)}{(1+\omega_{X,F}\eta)(1-\sigma)}}.$$

Finally,

$$X^M_{rs} = (\theta^F_{rs})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\kappa}} [\mu_{rs}]^{\frac{(1+\omega_{X,F}\eta)(1-\kappa)}{(1+\omega_{X,F}\kappa)(1-\eta)}} \left(\frac{X_{rs}}{[P_{rs}]^{1-\kappa}}\right)^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\kappa}}.$$

Thus,

$$P^F_{rs} = \zeta_{rs}\left(\frac{X_{rs}}{[P_{rs}]^{1-\kappa}}\right)^{\frac{\omega_{X,F}}{1+\omega_{X,F}\kappa}}, \tag{B.19}$$

$$\zeta_{rs} \equiv (\theta^F_{rs})^{\frac{\omega_{X,F}}{1+\omega_{X,F}\kappa}} [\mu_{rs}]^{\frac{1+\omega_{X,F}\eta}{(1+\omega_{X,F}\kappa)(1-\eta)}}.$$

We can also write

$$X^M_{irsg} = \varphi_{irsg}(\theta^F_{rsg})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\eta}} \left[\sum_{o\in\mathcal{R}_F}\varphi_{orsg}\right]^{\frac{(1+\omega_{X,F})(\sigma-\eta)}{(1+\omega_{X,F}\eta)(1-\sigma)}} \tag{B.20}$$

$$\times (\theta^F_{rs})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\kappa}} [\mu_{rs}]^{\frac{(1+\omega_{X,F})(\eta-\kappa)}{(1+\omega_{X,F}\kappa)(1-\eta)}} \left(\frac{X_{rs}}{[P_{rs}]^{1-\kappa}}\right)^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\kappa}}, \tag{B.21}$$

and, defining $T_{rs} \equiv \sum_{g\in\mathcal{G}_s}\sum_{i\in\mathcal{R}_F}\frac{t^{\text{ad-valorem}}_{ig}}{1+t^{\text{ad-valorem}}_{ig}} X^M_{irsg}$,

$$T_{rs} = \left(\frac{X_{rs}}{[P_{rs}]^{1-\kappa}}\right)^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\kappa}} \varphi^R_{rs}, \tag{B.22}$$

where

$$\varphi_{rs}^{R} = (\theta_{rs}^{F})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\kappa}} [\mu_{rs}]^{\frac{(1+\omega_{X,F})(\eta-\kappa)}{(1+\omega_{X,F}\kappa)(1-\eta)}} \sum_{g\in\mathcal{G}_s} (\theta_{rsg}^{F})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\eta}}$$
$$\times \left[\sum_{o\in\mathcal{R}_F} \varphi_{orsg}\right]^{\frac{(1+\omega_{X,F})(\sigma-\eta)}{(1+\omega_{X,F}\eta)(1-\sigma)}} \left(\sum_{i\in\mathcal{R}_F} \frac{t_{ig}^{\text{ad-valorem}}}{1+t_{ig}^{\text{ad-valorem}}} \varphi_{irsg}\right).$$

Now we go back to spending, which can be written as the solution of the following system:

$$X_{rs} - \sum_{d\in\mathcal{R}_H} \sum_{k\in\mathcal{S}} \hat{e}_{rsdk} (X_{dk})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\kappa}} = \tilde{X}_{rs}, \tag{B.23}$$

where

$$\tilde{X}_{rs} = \bar{X}_{rs} + \sum_{k\in\mathcal{S}} (\gamma_s \alpha_k + \alpha_{sk}) Y_{rk},$$
$$\hat{e}_{rsdk} = \gamma_s \frac{H_r}{H} \varphi_{dk}^{R} \left([P_{dk}]^{\kappa-1}\right)^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\kappa}}.$$

B.3 Numerical Algorithm

Given all parameters, we solve the model according to the following algorithm.

i. Compute parameters that are invariant to prices:

$$\zeta_{rs} \equiv (\theta_{rs}^{F})^{\frac{\omega_{X,F}}{1+\omega_{X,F}\kappa}} [\mu_{rs}]^{\frac{1+\omega_{X,F}\eta}{(1+\omega_{X,F}\kappa)(1-\eta)}},$$

$$\mu_{rs} = \sum_{g\in\mathcal{G}_s} (\theta_{rsg}^{F})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\eta}} \left[\sum_{i\in\mathcal{R}_F} \varphi_{irsg}\right]^{\frac{(1+\omega_{X,F}\sigma)(1-\eta)}{(1+\omega_{X,F}\eta)(1-\sigma)}},$$

$$\varphi_{irsg} = \left[\theta_{irg}^{X,F}(1+t_{ig}^{\text{ad-valorem}})\right]^{\frac{1-\sigma}{1+\omega_{X,F}\sigma}} (\theta_{irsg}^{F})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\sigma}},$$
$$\delta_{rs} \equiv \sum_{i\in\mathcal{R}_F} (\theta_{ris})^{-(1-1/\omega_{M,F})} \sum_{g\in\mathcal{G}_s} (\theta_{rig}^{M,F})^{1/\omega_{M,F}},$$

$$\varphi_{rs}^{R} = (\theta_{rs}^{F})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\kappa}} [\mu_{rs}]^{\frac{(1+\omega_{X,F})(\eta-\kappa)}{(1+\omega_{X,F}\kappa)(1-\eta)}} \sum_{g\in\mathcal{G}_s} (\theta_{rsg}^{F})^{\frac{1+\omega_{X,F}}{1+\omega_{X,F}\eta}},$$

$$\times \left[\sum_{o\in\mathcal{R}_F} \varphi_{orsg}\right]^{\frac{(1+\omega_{X,F})(\sigma-\eta)}{(1+\omega_{X,F}\eta)(1-\sigma)}} \left(\sum_{i\in\mathcal{R}_F} \frac{t_{ig}^{\text{ad-valorem}}}{1+t_{ig}^{\text{ad-valorem}}} \varphi_{irsg}\right).$$

ii. Guess $P_{rs}^{F,n=0}$:

$$P_{rs}^{F,0} = \zeta_{rs} \left(\tilde{D}_{rs}^{0}\right)^{\frac{\omega_{X,F}}{1+\omega_{X,F}\kappa}} \tag{B.24}$$

using a pre-determined choice of the sector-level demand shifter $\tilde{D}_{rs}^{0} \equiv X_{rs}^{0}(P_{rs}^{0})^{\kappa-1}$ (which could be the value in some observed initial equilibrium for example).

iii. Given $P_{rs}^{F,n}$, we have an inner loop that solves for p_{rs}^{n}.

(a) We guess $p_{rs}^{n,b=0}$.

(b) Given $\{P_{rs}^{F,n}, p_{rs}^{n,b}\}_s$, compute the vectors of sector-region variables (with length $|\mathcal{R}_H| \cdot |\mathcal{S}|$ and same ordering of sectors and regions for all variables).

i. Domestic sector-region price index $P_{rs}^{H,n,b}$ using (B.4) (requires $\tilde{\theta}_{ors}^{H} \equiv \bar{\theta}_{ors}^{H}/(\theta_{ors})^{1-\sigma}$ and σ):

$$P_{rs}^{H,n,b} = \left[\sum_{o\in\mathcal{R}_H} \tilde{\theta}_{ors}^{H} [p_{os}]^{1-\sigma}\right]^{\frac{1}{1-\sigma}}.$$

ii. Sector-region price index $P_{rs}^{n,b}$ using (B.3) (requires θ_{rk}^{c} and κ):

$$P_{rk}^{n,b} \equiv \left[\sum_{c=H,F} \theta_{rk}^{c} [P_{rk}^{c,n,b}]^{1-\kappa}\right]^{\frac{1}{1-\kappa}}.$$

iii. Sector-region supply $Y_{r,s}^{n,b}$ using (B.10) (requires α_s, $\alpha_{j,ks}$, and H_{rs}):

$$Y_{rs}^{n,b} = H_{rs}(p_{rs}^{n,b})^{1/\alpha_s} \prod_{k\in\mathcal{S}} [\alpha_{ks}/P_{rk}^{n,b}]^{\alpha_{ks}/\alpha_s}.$$

iv. Sector-region foreign demand $X_{rs}^{F,n,b}$ using (B.15) (requires $\delta_{j,s}$ and $\omega_{M,F}$):

$$X_{rs}^{F,n,b} = \delta_{rs}(p_{rs}^{n,b})^{1-1/\omega_{M,F}}.$$

v. Sector-region spending $X_{rs}^{n,b}$ using (B.23). Here, we have an inner fixed-problem algorithm (requires γ_{rs}, α_k, α_{sk}, H_r/H, $\varphi_{j,s}^{R}$, κ, and $\omega_{X,F}$):

A. Compute the vector $\tilde{X} = [\tilde{X}_{rs}]_{|\mathcal{R}_F|\cdot|\mathcal{S}|\times 1}$ and the matrix $\hat{e} \equiv [\hat{e}_{rs,dk}]_{|\mathcal{R}_F|\cdot|\mathcal{S}|\times|\mathcal{R}_F|\cdot|\mathcal{S}|}$ such that

$$\tilde{X}_{rs} = \bar{X}_{rs} + \sum_{k\in\mathcal{S}} (\gamma_s \alpha_k + \alpha_{sk})\, Y_{rk}^{n,b},$$

$$\hat{e}_{rs,dk} = \gamma_s \frac{H_r}{H} \varphi_{dk}^{R} \left([P_{dk}^{n,b}]^{\kappa-1}\right)^{\frac{1+\omega_{X,F}}{1+\omega_{X,F^\kappa}}}.$$

B. Guess that $X^{n,b,0} = \sum_{d=0}^{\bar{d}} \hat{e}^d \tilde{X}$. Given $X^{n,b,h}$, compute

$$\widetilde{X}_{rs}^{n,b,h} \equiv \sum_{d\in\mathcal{R}_H} \sum_{k\in\mathcal{S}} \hat{e}_{rs,dk} \left(X_{d,k}^{n,b,h}\right)^{\frac{1+\omega_{X,F}}{1+\omega_{X,F^\kappa}}} + \tilde{X}_{rs},$$

$$Xerr_{rs} \equiv X_{rs}^{n,b,h} - \widetilde{X}_{rs}^{n,b,h}.$$

If $max_{r,s}|Xerr_{rs}| < tol$, then we are done and we set $X^{n,b} = X^{n,b,h}$. Otherwise, repeat the step with

$$X_{rs}^{n,b,h+1} = X_{rs}^{n,b,h} - \psi^X \left(X_{rs}^{n,b,h} - \widetilde{X}_{rs}^{n,b,h}\right).$$

for $\psi^X > 0$ small enough. Note that, given the way we specify the initial guess, this should converge in a single step when $\omega^* = 0$. If the inversion for the initial guess is too slow, we can adapt the guess when $\omega^* > 0$.

vi. Sector-region domestic spending X_{rs}^H using (B.8) (requires θ_{rs}^H, κ)

$$X_{rs}^H \equiv \frac{\theta_{rs}^H [P_{rs}^{H,n,b}]^{1-\kappa}}{[P_{rk}^{n,b}]^{1-\kappa}} X_{rs}^{n,b}.$$

vii. Sector-region domestic demand using (B.8) and (B.14) (requires $\tilde{\theta}_{irs}^H \equiv \bar{\theta}_{irs}^H/(\theta_{irs})^{1-\sigma}$, σ):

$$X_{is}^{H,n,b} = \sum_{r\in\mathcal{R}_H} \frac{\tilde{\theta}_{irs}^H [p_{is}^{n,b}]^{1-\sigma}}{[P_{rs}^{H,n,b}]^{1-\sigma}} X_{rs}^{H,n,b}.$$

viii. Sector-region excess sector supply:

$$ESS_{rs}^{n,b} \equiv \frac{Y_{rs}^{n,b} - (X_{r,s}^{F,n,b} + X_{rs}^{H,n,b})}{Y_{rs}^{n,b}}.$$

(c) If $\max_{r,s}\{|ESS_{rs}^{n,b}|\} < tol$, then proceed to step 4 by setting $p_{rs}^n = p_{rs}^{n,b}$. If not, go back to (2.b) with new prices:

$$\ln p_{rs}^{n,b+1} = \ln p_{rs}^{n,b} - \psi^H ESS_{rs}^{n,b}$$

for $\psi^H > 0$ small enough. Intuition. Supply is larger than demand when $ESS_{rs}^{n,b} > 0$, so we reduce domestic prices in region r sector s until we converge.

iv. For the sector-level demand shifter $D_{rs}^n = E_{rs}^n (P_{rs}^n)^{\kappa-1}$, we compute the implied sector-level import price:

$$\tilde{P}_{rs}^{F,n} = \zeta_{rs} \left(D_{rs}^n\right)^{\frac{\omega_{X,F}}{1+\omega_{X,F}\kappa}}.$$

If $\max_{r,s}\{|P_{rs}^{F,n} - \tilde{P}_{rs}^{F,n}|\} < tol$, then stop. If not, go back to step 3 with new prices:

$$P_{rs}^{F,n+1} = \zeta_{rs} \left(\tilde{D}_{rs}^{n+1}\right)^{\frac{\omega_{X,F}}{1+\omega_{X,F}\kappa}},$$

with

$$\tilde{D}_{rs}^{n+1} = \tilde{D}_{rs}^n - \psi^F(\tilde{D}_{rs}^n - D_{rs}^n)$$

for $\psi^F > 0$ small enough.

v. Upon convergence, we compute X_{irsg}^M using (B.18), import prices p_{irg} using (B.17), import quantity $m_{irg} = X_{irsg}^M / p_{irg}^F$, pre-tariff import prices $p_{irg}^X \equiv p_{irg}/(1 + t_{ig}^{\text{ad-valorem}})$, sector-region value-added W_{rs} using (B.9), region-level consumption price index P_r^C using (B.12), and per-capita lump-sum transfers $\tau = \frac{1}{H}\sum_{r\in\mathcal{R}_H, s\in\mathcal{S}} T_{rs}$ with T_{rs} given by (B.22).

C Data and Calibration

This appendix details the procedure we use to calibrate the empirical model of Section 3 to the U.S. in 2017. We first describe our calibration procedure, taking as given the availability of data on the U.S. national accounts and input-output structure; GDP and employment in each state-sector pair; HS6-level trade data on imports and exports at the state level, as well as ad-valorem import tariffs at the national level; and state-to-state trade flow data for all merchandise goods. We then offer further details about data sources and cleaning methods.

C.1 Calibration

This section describes in detail the procedure we use to calibrate the model of Section 3. Concretely, we determine values of the following parameters:

$$\alpha_s, \alpha_{ks}, \gamma_s, \theta_{rds}, \theta^c_{rk}, \theta^c_{rkj}, \theta^c_{orsg}, \theta^{X,F}_{irg}, \theta^{M,F}_{rig}, \bar{X}_{rs}$$

in addition to employment H_{rs} and ad-valorem tariffs $t^{\text{ad-valorem}}_{ig}$, which we obtain directly from the data (see Section C.2).

As a first step, we normalize prices all domestic prices $p_{odg} = 1$. The price indices in B.1 imply that for all $r \in \mathcal{R}_H$, $s \in \mathcal{S}$, $c \in \{H, F\}$,

$$P^c_{rsg} = P^c_{rs} = P_{rs} = 1.$$

Following the treatment of domestic trade in Caliendo et al. (2018), we partition the set of sectors into internationally tradable sectors $\mathcal{S}^{F,T}$ and internationally non-tradable sectors $\mathcal{S}^{F,NT}$. We also separately partition the set of sectors into domestically tradable sectors $\mathcal{S}^{H,T}$ and domestically non-tradable sectors $\mathcal{S}^{H,NT}$. The domestically tradable sectors contain all internationally tradable sectors, as plus the wholesale and transportation sector. We describe explicitly below how to deal with the calibration of parameters related to sectors without trade flows.

Final production parameters: $\{\alpha_{ks}, \alpha_s, \theta_{rds}\}$ Data required: National IO tables for all sectors with information on gross output and sector-to-sector input spending flows, $\{Y^{IO}_s, Z^{IO}_{ks}\}$.

We set input shares α_{ks} according to sector s's spending on inputs from sector k:

$$\alpha_{ks} = \frac{Z^{IO}_{ks}}{Y^{IO}_s}.$$

We set the value-added share α_s equal to the share of s's revenue not spent on inputs:

$$\alpha_s = 1 - \sum_{k \in \mathcal{S}} \alpha_{ks}.$$

Finally, we back out θ_{rds} to be consistent with B.1 under our price normalization:

$$\theta_{rds} = [\alpha_s]^{-\alpha_s} \prod_{k \in S} [\alpha_{ks}]^{-\alpha_{k,s}}.$$

Home demand shifters: $\{\theta_{rds}, \theta^c_{rs}, \theta^c_{rsg}, \theta^c_{orsg}\}$ Data required: Import expenditures $\{X^M_{irsg}\}$ by country of origin, region of destination, sector of product, and product, in Home prices. Domestic trade flows $\{X^D_{irs}\}$ by region of origin, region of destination, and sector.

Using B.1, we set θ^F_{irsg}, θ^F_{rsg}, and θ^F_{rs} to match import flows

$$\theta^F_{irsg} = \frac{X^M_{irsg}}{X^M_{rsg}}, \quad \theta^F_{rsg} = \frac{X^M_{rsg}}{X^M_{rs}}, \quad \theta^F_{rs} = \frac{X^M_{rs}}{X_{rs}}.$$

Without loss of generality, we set $\theta^F_{irsg} = 1/|\mathcal{R}_F|$ when $X^M_{rsg} = 0$ and $\theta^F_{rsg} = 1/|\mathcal{G}_s|$ when $X^M_{rs} = 0$. These assignments play no role in our analysis. Note that $\theta^F_{rs} = 0$ for all internationally non-tradable sectors $s \in \mathcal{S}^{F,NT}$.

Using B.8, our price normalization, and the fact (see Section B.1) that $p_{rs} = \theta_{rds} p_{rdg}$ for all $d \in \mathcal{R}$ and $g \in \mathcal{G}_s$, we set θ^H_{rs} and $\bar{\theta}^H_{irs}$ to match domestic trade flows:

$$\bar{\theta}^H_{irs} = \frac{X^H_{irs}}{X^H_{rs}}, \quad \theta^H_{rs} = \frac{X^H_{rs}}{X_{rs}}$$

Without loss of generality, we set $\bar{\theta}^H_{irs} = 1/|\mathcal{R}_H|$. These assignments play no role in our analysis. Note that $\theta^H_{irs} = 0$ for all domestically non-tradable sectors $s \in \mathcal{S}^{H,NT}$, except when $i = r$. Finally, we recover θ^H_{irsg} from our assumption that $\theta^H_{irsg} = \bar{\theta}^H_{irs}$ and θ^H_{rsg} from our assumption that $\theta^H_{rsg} = \bar{\theta}^H_{rs} = 1/|\mathcal{G}_s|$.

Final demand parameters: $\{\gamma_j\}$ Data required: Final spending by sector F^{IO}_s in the national accounts.

We set γ_s equal to the share of s in total final spending:

$$\gamma_s = \frac{F^{IO}_s}{\sum_{s'} F^{IO}_{s'}}.$$

Foreign supply and demand shifters: $\{\theta_{irg}^{X,F}, \theta_{rig}^{M,F}\}$ Data required: Import expenditures $\{X_{irsg}^{M}\}$ by country of origin, region of destination, sector of product, and product, in Home prices. Export revenues $\{X_{risg}^{F}\}$ by region of origin, country of destination, sector of product, and product, in Home prices.

Using 20, we set foreign export supply shifters $\{\theta_{irg}^{X,F}\}$ to match observed Home imports under our price normalization:

$$\theta_{irg}^{X,F} = (1 + t_{ig}^{\text{ad-valorem}})^{-1} (X_{irg}^{M})^{-\omega_{X,F}}.$$

Similarly, using 20, we set foreign import demand shifters $\{\theta_{rig}^{M,F}\}$ to match observed Home exports under our price normalization:

$$\theta_{rig}^{M,F} = (X_{rig}^{F})^{\omega_{M,F}}.$$

Demand imbalances: $\{\bar{X}_{rs}\}$ Data required: Import expenditures $\{X_{irsg}^{M}\}$ by country of origin, region of destination, sector of product, and product, in Home prices. Ad-valorem tariffs $\{t_{ig}^{\text{ad-valorem}}\}$ by country of origin and product. Population by region $\{H_r\}$. Domestic trade flows $\{X_{irs}^{D}\}$by region of origin and destination, by sector. Gross output $\{Y_{rs}\}$ by sector and region.

We first compute lump-sum transfers per household:

$$\tau = \frac{1}{H} \sum_{i \in \mathcal{R}_F} \sum_{r \in \mathcal{R}_H} \sum_{s \in \mathcal{S}} \sum_{g \in \mathcal{G}_s} \frac{t_{ig}^{\text{ad-valorem}}}{1 + t_{ig}^{\text{ad-valorem}}} X_{irsg}^{M}.$$

We next compute its each region r's total spending on sector $s$as

$$X_{rs} = \sum_{o \in \mathcal{R}_H} X_{ors}^{D} + \sum_{i \in \mathcal{R}_F} X_{irs}^{M}.$$

We then use B.13 to solve for imbalances $\bar{X}_{rs}$ as the excess demand required markets to clear:

$$\bar{X}_{rs} = X_{rs} - \gamma_s \left(\sum_{k \in \mathcal{S}} \alpha_k Y_{rk} + H_r \tau \right) - \sum_{k \in \mathcal{S}} \alpha_{sk} Y_{rk}.$$

C.2 Data

We use the following data sources and cleaning procedures to calibrate the model. All data is for the year 2017.

i. **Definitions.**

(a) Domestic regions $\mathcal{R}_H$ are US states plus Washington, DC, so that $|\mathcal{R}_H| = 51$ states.

(b) Foreign countries $\mathcal{R}_F$ are the top 100 US trade partners, plus the rest of the world treated as a single country. In 2017, the US's top 100 trade partners account for 99.4% of trade, 99.0% of exports, 99.6% of imports.

(c) We use a set of 29 industries $\mathcal{S}$ obtained by coarsening the 2 and 3-digit NAICS used in regional/national accounts and the CFS. There are 21 domestically and internationally tradable sectors, 1 domestically tradable but internationally non-tradable sector (wholesale and transportation), and 7 domestically and internationally non-tradable sectors.

(d) We use HS6 as our product classification and build a crosswalk from HS6 to our sector classification, $\mathcal{G}_s$, based on the HS10-NAICS classification in Fajgelbaum et al. (2020). Specifically, for each HS6, we compute the share of trade (exports+imports) on different sectors and associate that HS6 to the sector with the highest trade share. Given our coarse sector classification, the trade share of the sector is above 99% for 90% of the HS6 products. In 2017, there are 5,299 products with positive trade and that we link to one of our sectors.

ii. **BEA National IO tables.** We use the BEA's make-use tables (before redefinitions) to obtain consistent national accounts for 71 industries, which include 19 in manufacturing, 2 agriculture (farm and forestry), and 3 mining (oil/gas, other mining, and support activities).

(a) We map the national accounts from commodity×industry space to industry×industry space by assuming each industry supplies the same output bundle of commodities and demands the same input bundle of commodities, whichever buyers it interacts with. We then map the 71-industry accounts to our final industry classification using their NAICS codes.

(b) Final output: Sector-level national gross output $\{Y_s^{IO}\}$, exports $\{EXP_s^{IO}\}$, imports (inclusive of tariffs) $\{IMP_s^{IO}\}$, final spending $\{F_s^{IO}\}$, and value added $\{\Pi_s^{IO}\}$, and sector-by-sector input spending flows $\{Z_{ks}^{IO}\}$.

iii. **BEA regional accounts.** We use the BEA's regional accounts to obtain state-level GDP/employment for an industry classification that is similar to the one used in the national accounts.

(a) Let $\widetilde{GDP}_{rs}$ be the GDP from the regional accounts aggregated to our 29-sector classification. We adjust magnitude of regional-sector GDP to be consistent with aggregate sector-level GDP in the national accounts: $GDP_{rs} = \kappa_s^{GDP} \widetilde{GDP}_{rs}$ with $\kappa_s^{GDP} = \Pi_s^{IO} / \sum_{r \in \mathcal{R}_H} GDP_{rs}$.

(b) Final output: Employment $\{Emp_{rs}\}$ and GDP $\{GDP_{rs}\}$, by state r and sector s.

iv. **US Census.**

(a) We use regional trade data on the imports and exports of every U.S. state, by trading partner, by HS6 good.

i. We obtain exports $\{\tilde{X}^F_{irg}\}$ by origin country i, destination state r, and HS6 good g and imports $\{\tilde{X}^M_{rig}\}$ by origin state r, destination country i, and HS6 good g,directly from the U.S. Census (import value CIF and export value FOB). [45]

(b) We use national trade data to compute matrices of ad-valorem tariffs, $[t_{ig}^{\text{ad-valorem}}]$ with dimension $|\mathcal{R}_F| \times \max_s |\mathcal{G}_s|$ with foreign country in the row and product in the column. We compute $t_{ig} = \text{calculated duty}_{ig} / \text{import value FOB}_{ig}$ for each country i and for all "rest-of-world" countries as a single group.

(c) We adjust the magnitudes of exports and imports to be consistent with industry-level import values in the national accounts.

i. Exports: For all internationally tradable sectors $s \in \mathcal{S}^{F,T}$, for all $g \in \mathcal{G}_s$, define rescaled FOB exports $X^F_{rig} = \kappa^F_s \tilde{X}^F_{rig}$ where $\kappa^F_s = EXP^{IO}_s / \sum_{r \in \mathcal{R}_H, i \in \mathcal{R}_F, g \in \mathcal{G}_s} \tilde{X}^F_{rig}$.

ii. Imports: For all internationally tradable sectors $s \in \mathcal{S}^{F,T}$, for all $g \in \mathcal{G}_s$, define rescaled CIF + tariff imports $X^M_{irg} = \kappa^M_s (1 + t_{ig}) \tilde{X}^M_{irg}$, where $\kappa^M_s = IMP^{IO}_s / \sum_{r \in \mathcal{R}_H, i \in \mathcal{R}_F, g \in \mathcal{G}_s} (1 + t_{ig}) \tilde{X}^M_{irg}$.

[45] We only observe customs data for manufacturing, agriculture, and oil/mining (more precisely, the 2-digit sectors 11, 21, 31, 32, and 33). We assume that there is no trade in all other sectors—notably including services. This is consistent with the assumption of them being "non-tradable" that we will impose below for domestic trade across US states; it makes little sense to have them as domestically non-tradable, but make them tradable across countries.

The omission of trade in non-merchandise sectors does not directly affect the estimation procedure, as we have no tariff data on these sectors. However, their omission may shape the Jacobian of real wages with respect to tariffs, which we use in our estimation procedure.

In order to ensure that markets clear even though we ignore non-merchandise trade, we calibrate the exogenous net demands $\bar{X}_{rs}$ to meet supply in each region-sector pair. This approach has large implications for the US current account: Accounting for all exports/imports in the national accounts, exports are \$2.1 trillion and imports are \$2.6 trillion. Accounting for only trade in the sectors where we observe trade data, exports are \$1.0 trillion and imports are \$2.1 trillion. For reference, US GDP is \$19.5 trillion.

(d) For each region-sector pair (r, s), we impute gross output as the maximum of exports and GDP-implied production at national value-added shares

$$Y_{rs} = \max\left\{\frac{GDP_{rs}}{1-\alpha_s^{IO}}, X_{rs}^F\right\},$$

where $1-\alpha_s^{IO} = \Pi_s^{IO}/Y_s^{IO}$ is the value-added share of sector s in the IO tables. This imputed gross output exceeds $\frac{GDP_{rs}}{1-\alpha_s^{IO}}$ in only 3% of region-sector pairs, and the total amount of excess across all region-sector pairs is less than 0.2% of aggregate GDP.

(e) Final output: US import expenditures $\{X_{irg}^M\}$ by origin country i, destination state r, and product g. US export revenues $\{X_{rig}^F\}$ by origin state r, destination country i, and product g. Gross output $\{Y_{rs}\}$ by state $r$and sector s.

v. **Commodity Flow Survey.**

(a) From the CFS microdata, we compute the value of state-to-state domestic shipments for each of tradable sectors that appear in the CFS data.

i. We map the CFS sectors (based on 3-digit NAICS) to our 29 sectors.

ii. We then adjust the magnitude of domestic shipments within each tradable industry to match its domestic usage in the National accounts.

(b) For every pair of domestic regions $i, r \in \mathcal{R}_H$ and every sector $s \in \mathcal{S}$, we impute the share of i's domestic shipments of $s$that are sent to r, $share_{irs}$, as follows:

i. If s is domestically non-traded, i.e., $s \in \mathcal{S}^{H,NT}$, then all shipments are local:

$$share_{irs} = \begin{cases} 1 & \text{if } i = r; \\ 0 & \text{if } i \neq r. \end{cases}$$

ii. If s is domestically traded, i.e. $s \in \mathcal{S}^{H,T}$, and s is contained in the CFS data, then we set

$$share_{irs} = \frac{X_{irs}^{CFS}}{\sum_{d\in\mathcal{R}_H} X_{ids}^{CFS}}.$$

iii. There are two domestically tradable sectors without domestic shipment data in the CFS: agriculture 11 and oil 211. Under the assumption that non-exported output is shipped domestically, these sectors account for 7.7% of all domestic shipments. For $s = 11,\ 211$, we impute

$$share_{irs} = \frac{\sum_{k \in CFS} X_{irk}^{CFS}}{\sum_{d \in \mathcal{R}_H} \sum_{k \in CFS} X_{idk}^{CFS}}.$$

iv. There are two domestically tradable sectors (motor vehicles and other transportation equipment) that are associated with the same CFS sector (NAICS 336). Under the assumption that non-exported output is shipped domestically, these sectors account for 9.2% of all domestic shipments. We assume that both have the same domestic trade shares, i.e. for $s = 3361, 3364$, we impute

$$share_{irs} = \frac{X_{ir336}^{CFS}}{\sum_{d \in \mathcal{R}_H} X_{id336}^{CFS}}.$$

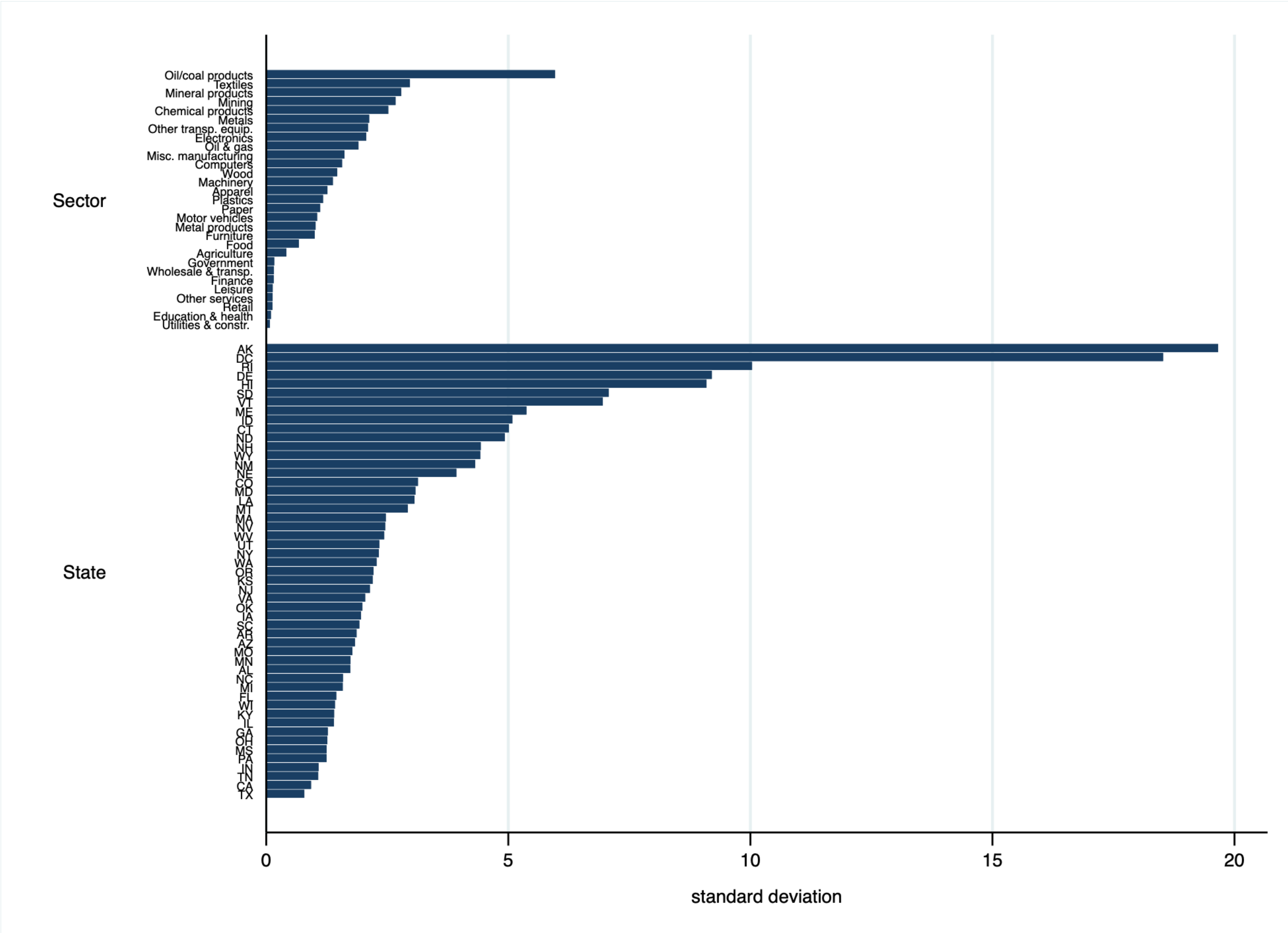
(c) Finally, we impute total domestic shipments of sector s from region i to region r as the difference between i's output of s and its exports, times the share of its domestic flows of s that it sends to r:

$$X_{irs}^{D} = share_{irs}(Y_{rs} - X_{rs}^{F}).$$

(d) Final output: Domestic spending flows $\{X_{irs}^{D}\}$ of sector s from origin state i to destination state r.

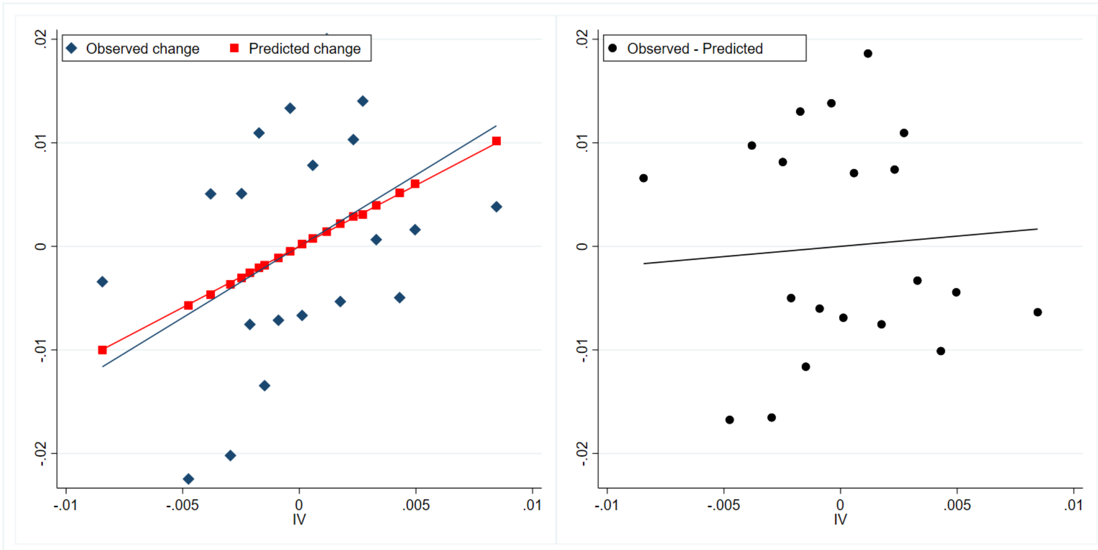
D Additional Results

Figure D.1: Standard deviation of real earnings impacts due to imports



Notes: This figure reports the standard deviation of $\partial(\omega_{rs} - \bar{\omega})/\partial m_{ig}$, taken across all origin countries i and products g, separately for each sector and state.

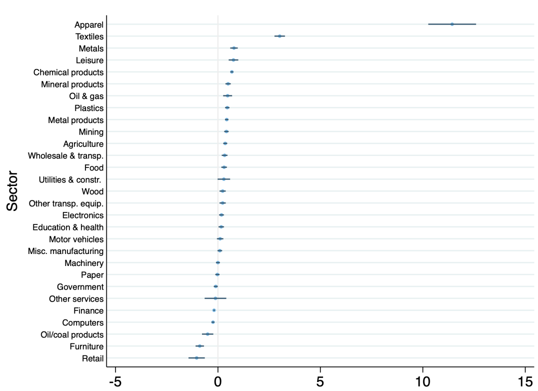
Figure D.2: Observed versus Predicted Changes in Earnings during Trump's Trade War



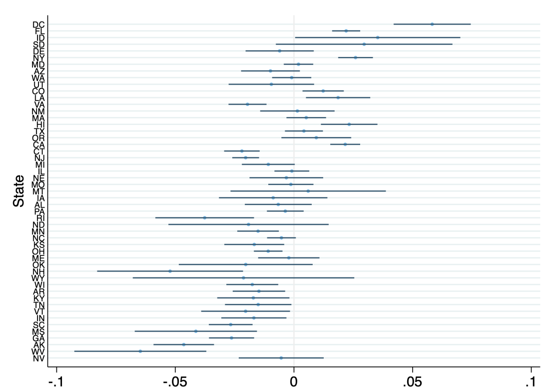
Notes: The left figure plots observed and predicted changes in earnings per worker against our IV and the right figure plots the difference between observed and predicted changes against our IV. Each figure displays a binned scatter plot in which the underlying sector-state observations are grouped into 20 bins in terms of the IV, weighted by initial employment.

Figure D.3: Estimates of welfare weights across sectors and regions (composition-adjusted)

(a) $\hat{\beta}_s$ estimates (composition-adjusted)



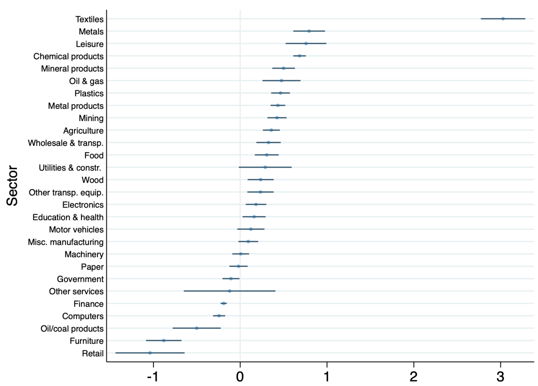
(b) $\hat{\beta}_r$ estimates (composition-adjusted)



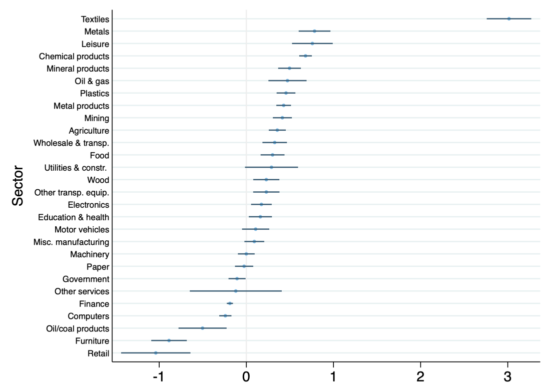
Notes: Panels (a) and (b) display composition-adjusted versions of sector- and region-based welfare weights computed as $\tilde{\beta}_s \equiv \beta_s + \sum_r \left(\frac{H_{sr}}{H}\right) \beta_r$ and $\tilde{\beta}_r \equiv \beta_r + \sum_s \left(\frac{H_{sr}}{H}\right) \beta_s$, respectively. Light blue dots correspond to point estimates and bars denote 95% confidence intervals. Standard errors are clustered at the product-level.

Figure D.4: Estimates of sector-based welfare weights (omitting Apparel sector)

(a) $\hat{\beta}_s$ estimates



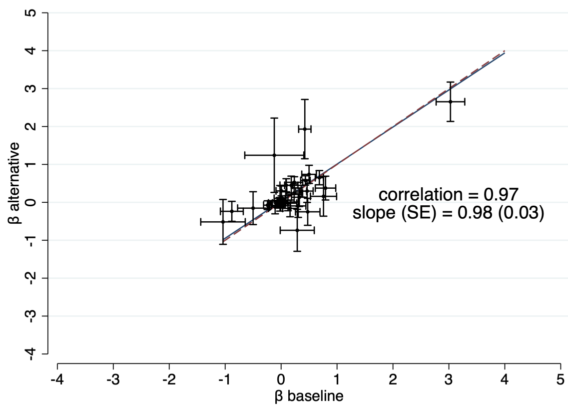
(b) $\hat{\beta}_s$ estimates (composition-adjusted)



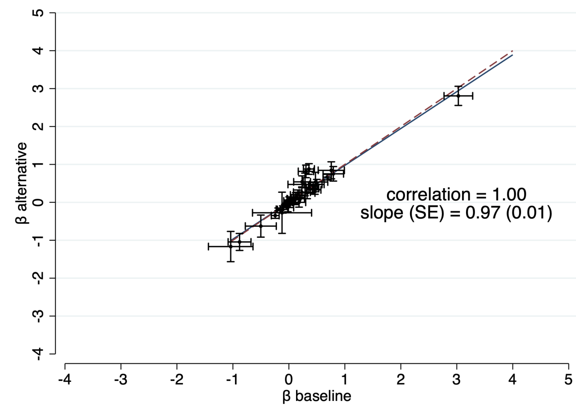
Notes: Panel (a) displays estimates of the marginal social return, β_s, for each sector s, as obtained from equation (24) and normalized such that the mean of $\hat{\beta}_s$ across s is zero. Panel (b) displays composition-adjusted versions computed as $\tilde{\beta}_s \equiv \beta_s + \sum_r \left(\frac{H_{sr}}{H}\right) \beta_r$. Light blue dots correspond to point estimates and bars denote 95% confidence intervals. In both cases, the Apparel sector (shown in Figure 4) is omitted for clarity. Standard errors are clustered at the product-level.

Figure D.5: Sensitivity analysis (omitting Apparel sector)

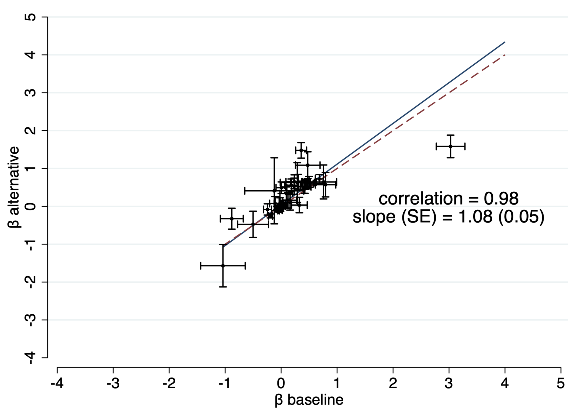
(a) Subsample without NTMs



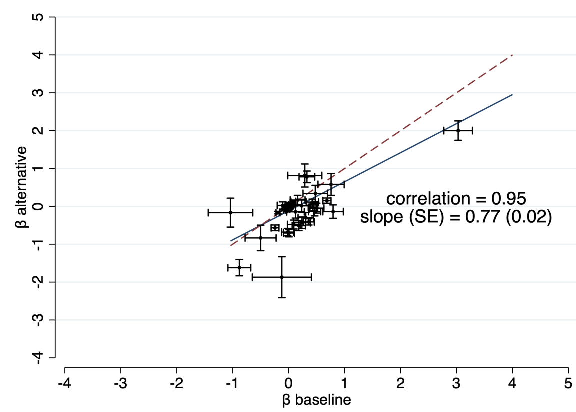
(b) NTM Controls



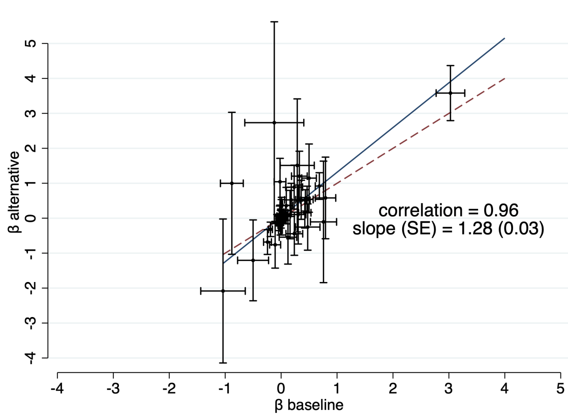
(c) Flexible terms-of-trade



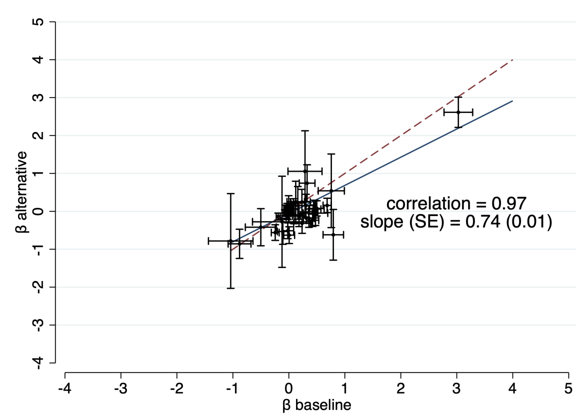
(d) IV for simultaneity



(e) Unconstrained tariff setting

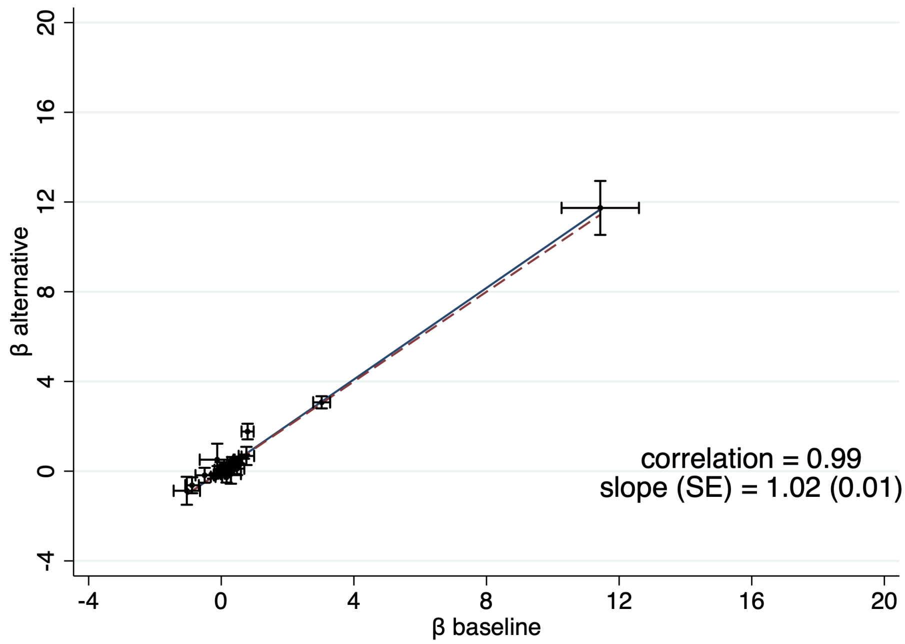


(f) Product-level sample



Notes: Each figure displays the relationship between baseline estimates (of $\hat{\beta}_s$ and $\hat{\beta}_r$ across all sectors s and regions r) on the x-axis and estimated values obtained under alternative assumptions (described in the text) on the y-axis. The solid blue line illustrates the line of best fit (whose slope and standard error are reported) and the dashed red line indicates the 45-degree line. See Section 4.3 for details. In all cases, the estimate for the Apparel sector (shown in Figure 6) has been omitted for clarity. Bars indicate 95% confidence intervals on each estimate.

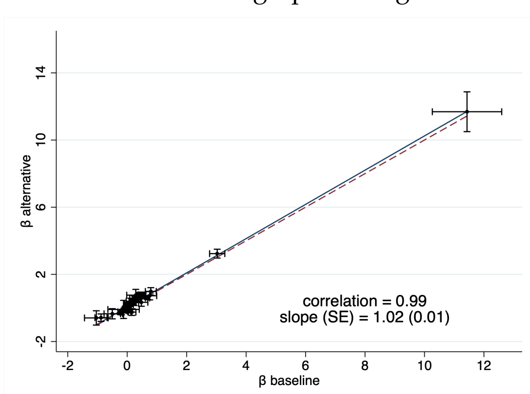
Figure D.6: Robustness to including antidumping and countervailing duty rates



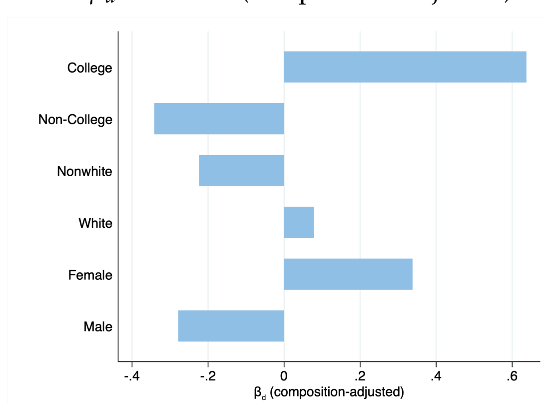
Notes: This figure displays the relationship between baseline estimates (of $\hat{\beta}_s$ and $\hat{\beta}_r$ across all sectors s and regions r) on the x-axis and estimated values obtained under an alternative, on the y-axis, in which the measure of tariffs t_{ig} used includes antidumping and countervailing duties. The solid blue line illustrates the line of best fit (whose slope and standard error are reported) and the dashed red line indicates the 45-degree line. Bars indicate 95% confidence intervals on each estimate.

Figure D.7: Estimates of welfare weights incorporating demographic groups

(a) $(\hat{\beta}_r, \hat{\beta}_s)$ estimates, obtained with and without addition of demographic categories

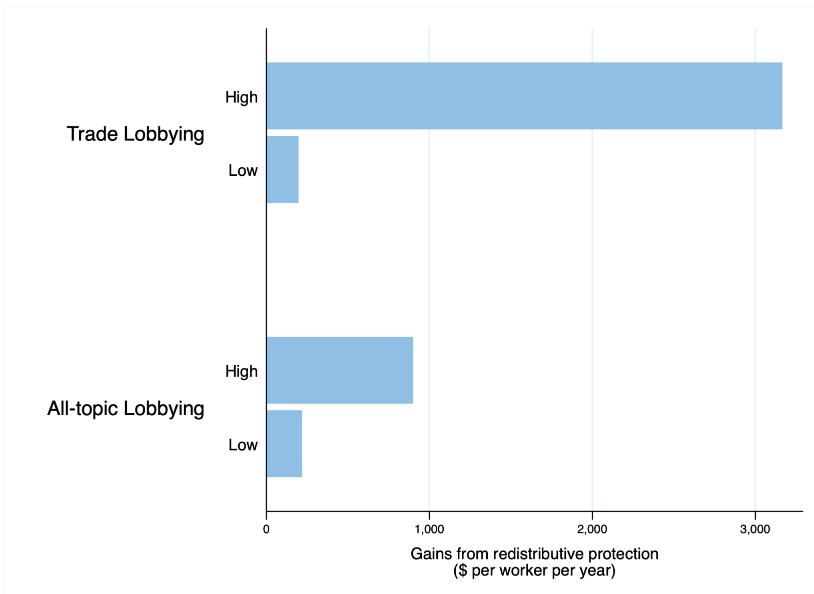


(b) $\widetilde{\beta}_d$ estimates (composition-adjusted)



Notes: Panel (a) reports how estimates of $\hat{\beta}_r$ and $\hat{\beta}_s$ change, relative to the baseline version, when including demographic characteristics in the determination of households' welfare weights. Panel (b) displays the estimated values of (composition-adjusted) demographic determinants of welfare weights, computed as $\widetilde{\beta}_d \equiv \hat{\beta}_d + \sum_{r,s} \left(\frac{H_{rsd}}{H_{rs}}\right) (\hat{\beta}_r + \hat{\beta}_s)$.

Figure D.8: Lobbying and Gains from Redistributive Protection



Notes: This figure plots the gains from redistributive protection, defined as minus the real income loss of going from the factual 2017 values of the US tariffs to their counterfactual values in the absence of redistributional motives, for different groups of US households.

Table D.1: Sensitivity analysis for estimates of β_{rs}

	All (1)	Drop apparel (2)	Sectors only (3)	Sectors, excl. apparel (4)	Regions only (5)
Panel (a): Subsample without NTMs					
Slope	1.28	1.06	1.27	1.01	1.35
(SE)	(0.03)	(0.19)	(0.04)	(0.24)	(0.32)
Correlation	0.96	0.66	0.95	0.63	0.39
Panel (b): NTM controls					
Slope	0.97	1.01	0.97	1.00	1.00
(SE)	(0.01)	(0.05)	(0.01)	(0.06)	(0.07)
Correlation	1.00	0.97	1.00	0.97	0.96
Panel (c): Flexible terms-of-trade controls					
Slope	1.08	0.74	1.06	0.67	1.09
(SE)	(0.05)	(0.17)	(0.05)	(0.19)	(0.18)
Correlation	0.98	0.79	0.98	0.78	0.75
Panel (d): IV for simultaneity					
Slope	0.77	0.66	0.80	0.77	0.67
(SE)	(0.02)	(0.10)	(0.02)	(0.12)	(0.21)
Correlation	0.95	0.65	0.96	0.74	0.58
Panel (e): Unconstrained tariff setting					
Slope	1.28	1.06	1.27	1.01	1.35
(SE)	(0.03)	(0.19)	(0.04)	(0.24)	(0.32)
Correlation	0.96	0.66	0.95	0.63	0.39
Panel (f): Product-level sample					
Slope	0.77	0.66	0.80	0.77	0.67
(SE)	(0.02)	(0.10)	(0.02)	(0.12)	(0.21)
Correlation	0.95	0.65	0.96	0.74	0.58
Panel (g): Omit terms-of-trade control					
Slope	1.05	0.99	1.05	0.98	0.99
(SE)	(0.01)	(0.03)	(0.01)	(0.04)	(0.03)
Correlation	1.00	0.99	1.00	0.99	0.99
Panel (h): Omit constant					
Slope	1.23	0.82	1.25	0.86	0.58
(SE)	(0.04)	(0.15)	(0.04)	(0.14)	(0.13)
Correlation	0.98	0.76	0.98	0.77	0.64

Notes: Each panel reports the results of a regression of alternative estimates of $\beta_{rs} = \beta_r + \beta_s$ on baseline estimates of β_{rs}, where the alternative estimates are obtained under the specifications described in Section 4.3. The regressions reported in column (1) use values of $\widehat{\beta}_{rs}$ from all regions r and sectors s, whereas those in column (2) drop the apparel sector, column (3) uses only the values of $\widehat{\beta}_s$, column (4) uses $\widehat{\beta}_s$ but without the apparel sector, and column (5) uses only the values of $\widehat{\beta}_r$.