SUPPLEMENTARY MATERIAL FOR "WHY IS TRADE NOT FREE? A REVEALED PREFERENCE APPROACH"

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APPENDIX A: THEORETICAL APPENDIX

A.1. *Proof of Proposition 1*

PROOF: Start from the Lagrangian associated with the government's problem,

$$\mathcal{L} = u(c(n_0), z; n_0) + \sum_{n \neq n_0} \nu(n)[u(c(n), z; n) - \underline{u}(n)],$$

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

$$\sum_{n \in \mathcal{N}} \nu(n) du(n) = 0, \tag{A.1}$$

where we use the convention $\nu(n_0) = 1$.

In a competitive equilibrium, utility maximization by individual n, as described in (6), and the government's budget balance, as described in (8), imply

$$e(p, z, u(n); n) = \pi \cdot \phi(n) + \frac{1}{N}(t^* \cdot m).$$

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

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

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

Next, consider profit maximization by firm f, as described in (5). By the same envelope argument, the change in firm f's profits satisfies

$$d\pi(f) = y(f) \cdot dp + \pi_z(f) \cdot dz, \tag{A.3}$$

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

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

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

From the good market clearing condition (7), we know that $m = \sum_{n\in\mathcal{N}} c(n) - \sum_{f\in\mathcal{F}} y(f)$. Since $\sum_{n\in\mathcal{N}} \phi(f,n) = 1$, it follows that $m \cdot dp = -\sum_{n\in\mathcal{N}} d\omega(n)$ and, in turn, that

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

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

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

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

The previous condition implies

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

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

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

with $t^{*T} \equiv \{t_g^*\}_{g\in\mathcal{G}^T}$ the vector of potentially non-zero trade taxes and $m^T \equiv \{m_g\}_{g\in\mathcal{G}^T}$ 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

$$t_g^* = -\beta \cdot \frac{\partial(\omega - \bar{\omega})}{\partial m_g} + m \cdot \frac{\partial p^w}{\partial m_g} + \epsilon \cdot \frac{\partial z}{\partial m_g} \text{ for all } g \in \mathcal{G}^T.$$

This concludes the proof of Proposition 1. *Q.E.D.*

A.2. *Extensions of Proposition 1*

Other Policy Instruments (a): Non-Tariff Measures. Consider a generalized version of the environment of Section 2.1 in which Home's government may also impose two types of non-tariff measures. The first one $s^{NTM} \in \mathcal{S}^{NTM}$ is a potentially high-dimensional vector that captures all product standards, environmental regulations, labor standards, and quantity restrictions that the government may decide to impose on domestic firms, domestic individuals, and foreign firms. Such non-tariff measures may affect domestic firms' production sets, $\Upsilon(z, s^{NTM}; f)$; domestic individuals' utility, $u(c(n), z, s^{NTM}; n)$; as well as Foreign's offer curve $\Omega(p^w, z, s^{NTM})$. The second type of non-tariff measures $t^{NTM} \equiv \{t_g^{NTM}\} \in \mathcal{T}^{NTM}$ are extra charges such as anti-dumping and countervailing duties.[1] Although such non-tariff measures are legally distinct from tariffs, they affect prices and the government's revenues in the exact same way. That is, the non-arbitrage condition (2) generalizes to

$$p_g = p_g^w + t_g + t_g^{NTM}, \tag{A.4}$$

whereas the domestic government's budget constraint (8) becomes

$$m \cdot (t + t^{NTM}) = N\tau. \tag{A.5}$$

In the presence of non-tariff measures, Proposition 1 generalizes as follows.

PROPOSITION A.1—Non-Tariff Measures: *Suppose that Home's government has access to non-tariff measures $s^{NTM} \in \mathcal{S}^{NTM}$ and $t^{NTM} \in \mathcal{T}^{NTM}$. Then Pareto efficient trade taxes satisfy*

$$t_g^* = -\beta \cdot \frac{\partial(\omega - \bar{\omega})}{\partial m_g} + m \cdot \frac{\partial p^w}{\partial m_g} + \epsilon \cdot \frac{\partial z}{\partial m_g} - t_g^{NTM} \text{ for all } g \in \mathcal{G}^T. \tag{A.6}$$

PROOF: For given non-tariff measures $s^{NTM} \in \mathcal{S}^{NTM}$ and $t^{NTM} \in \mathcal{T}^{NTM}$, the same arguments as in the proof of Proposition 1 imply

$$(t^* + t^{NTM}) \cdot dm = -\beta \cdot d(\omega - \bar{\omega}) + m \cdot dp^w - \epsilon \cdot dz, \tag{A.7}$$

where we have used the fact that t and t^{NTM} only enter equilibrium conditions through their sum, as can be seen from (A.4) and (A.5). Equation (A.6) then follows from (A.7) for the same reasons as in the proof of Proposition 1. *Q.E.D.*

Other Policy Instruments (b): Domestic Taxes and Subsidies. Consider a generalized version of the environment of Section 2.1 in which, in addition to trade taxes, the government may now impose producer subsidies $s^y(f) \equiv \{s_g^y(f)\} \in \mathcal{S}^y(f)$, as well as income tax schedules $T(\cdot; n) \in \mathcal{T}(n)$. Note that production subsidies may vary across firms, perhaps because they operate in different sectors or regions, and income tax schedules may vary across individuals, perhaps because of differences in marital status or state of residence. Let p denote the vector of prices faced by domestic individuals and $q(f)$ the vector of prices faced by firm f. The non-arbitrage condition (2) now generalizes to

$$p_g = p_g^w + t_g, \tag{A.8}$$

$$q_g(f) = p_g^w + t_g + s_g^y(f). \tag{A.9}$$

In turn, the profit maximization problem of a given firm f is

$$\max_{y \in \Upsilon(z;f)} q(f) \cdot y, \tag{A.10}$$

with $\pi(q(f), z; f)$ the associated value function. Income taxes, in turn, affect the budget constraint of individuals

$$p \cdot c(n) = \pi \cdot \phi(n) - T[\pi \cdot \phi(n); n] + \tau, \tag{A.11}$$

[1]Quotas may belong to either the first or the second type of non-tariff measures depending on whether or not the domestic government sells importing rights.

as well as the budget constraint of the domestic government,

$$t \cdot m - \sum_{f \in \mathcal{F}} s^y(f) \cdot y(f) + \sum_{n \in \mathcal{N}} T[\pi \cdot \phi(n); n] = N\tau, \tag{A.12}$$

All other equilibrium conditions are unchanged.

Let $t(n) \equiv T'[\pi \cdot \phi(n); n]$ denote the marginal income tax rate faced by individual n and let $\partial\omega_{\text{post-tax}}(n)/\partial m_g \equiv [1 - t(n)] \times [y(n) \cdot \partial q/\partial m_g] - c(n) \cdot \partial p/\partial m_g$ denote the after-tax change in individual n's real income caused by the increase in net imports of good g via its impact on domestic prices p and q. In line with our previous analysis, let $\partial\bar{\omega}_{\text{post-tax}}/\partial m_g \equiv \sum_{n \in \mathcal{N}} [\partial\omega_{\text{post-tax}}(n)/\partial m_g]/N$ denote the average change in post-tax real incomes across the population and let $\partial(\omega - \bar{\omega})_{\text{post-tax}}/\partial m_g \equiv \{\partial(\omega_{\text{post-tax}}(n) - \bar{\omega}_{\text{post-tax}})/\partial m_g\}$ denote the vector of deviations from the average. Using this new notation, we can state our next generalization of Proposition 1 as follows.

PROPOSITION A.2—Domestic Taxes: *Suppose that Home's government has access to producer subsidies $s^y(f) \in \mathcal{S}^y(f)$ and income tax schedules $T(\cdot; n) \in \mathcal{T}(n)$. Then Pareto efficient trade taxes satisfy*

$$t_g^* = -\beta \cdot \frac{\partial(\omega - \bar{\omega})_{\textit{post-tax}}}{\partial m_g} + m \cdot \frac{\partial p^w}{\partial m_g} + \tilde{\epsilon} \cdot \frac{\partial z}{\partial m_g} + \sum_{f \in \mathcal{F}} s^y(f) \cdot \frac{\partial y(f)}{\partial m_g} \textit{ for all } g \in \mathcal{G}^T, \tag{A.13}$$

where $\tilde{\epsilon} \equiv \sum_{n \in \mathcal{N}} \beta(n)[e_z(n) - [1 - t(n)]\pi_z(n)] - \sum_{n \in \mathcal{N}} t(n)\pi_z(n)$ denotes the social marginal cost of externalities in the presence of income taxation.

PROOF: For given producer subsidies $s^y(f) \in \mathcal{S}^y(f)$ and income tax schedules $T(\cdot; n) \in \mathcal{T}(n)$, utility maximization by individual n, subject to the new budget constraint (A.11), and the government's budget balance, as described in (A.12), imply

$$\begin{aligned} e(p, z, u(n); n) = &\pi \cdot \phi(n) - T[\pi \cdot \phi(n); n] \\ &+ \frac{1}{N}\left(t^* \cdot m - \sum_{f \in \mathcal{F}} s^y(f) \cdot y(f) + \sum_{n' \in \mathcal{N}} T[\pi \cdot \phi(n'); n']\right). \end{aligned}$$

Differentiating the previous expression and following the same steps as in the proof of Proposition 1 implies

$$\begin{aligned} du(n) = \mu(n)\{&d\omega_{\text{post-tax}}(n) - d\bar{\omega}_{\text{post-tax}} + \{[1 - t(n)]\pi_z(n) - e_z(n)\} \cdot dz \\ &+ \frac{1}{N}\{t^* \cdot dm - m \cdot dp^w - \sum_{f \in \mathcal{F}} s^y(f) \cdot dy(f) + \sum_{n' \in \mathcal{N}} t(n')[\pi_z(n') \cdot dz]\}\}, \end{aligned}$$

with $d\omega_{\text{post-tax}}(n) \equiv [1 - t(n)][y(n) \cdot dq] - c(n) \cdot dp$ and $d\bar{\omega}_{\text{post-tax}} \equiv \sum_{n \in \mathcal{N}} d\omega_{\text{post-tax}}(n)/N$. Substituting this expression in the first-order condition (A.1) and following again the same steps as in the proof of Proposition 1 implies (A.13). *Q.E.D.*

It is worth noting that there are no fiscal externalities associated with income taxes in (A.13). This reflects our assumption that individuals only earn income through ownership of firms. This allows for fixed factor endowments, but not elastic factor supply.

Constrained Trade Taxes. Consider a generalized version of the environment of Section 2.1 in which trade taxes are constrained in two ways. First, for goods $g \in \mathcal{G} - \mathcal{G}^T \equiv \mathcal{G}^{-T}$, we assume that trade taxes are fixed at some level $\bar{t} \equiv \{\bar{t}_g\}_{g \in \mathcal{G}^{-T}}$, perhaps because of some prior trade agreements. Second, for goods $g \in \mathcal{G}^T$, we assume that trade taxes are coarse and must now take the same values across subsets of goods, for instance because the domestic government may not discriminate between different foreign origins. Formally, we assume that that there is a partition of the set of goods $g \in \mathcal{G}^T$ into groups indexed by G such that $t_g = \hat{t}_G$ for all goods in group G. Except for the previous constraint, the government can freely choose the level of the tax $\hat{t}_G$ on each group G. The environment of Section 2.1 corresponds to the special case in which $\bar{t} = 0$ and each group G consists of a single good. In this alternative environment, Proposition 1 extends as follows.

PROPOSITION A.3—Constrained Trade Taxes: *Suppose that:* (i) $t_g = \bar{t}_g$ *for all* $g \in \mathcal{G}^{-T}$, *with* $\bar{t}_g$ *exogenously given, and* (ii) $t_g = \hat{t}_G$ *for all* $g \in \mathcal{G}^T$ *in group* G, *with* $\hat{t}_G$ *freely chosen by the government. Then Pareto efficient trade taxes satisfy*

$$t_g^* = -\beta \cdot \frac{\partial(\omega - \bar{\omega})}{\partial M_G} + m \cdot \frac{\partial p^w}{\partial M_G} + \epsilon \cdot \frac{\partial z}{\partial M_G} - \bar{t} \cdot \frac{\partial \bar{m}}{\partial M_G} \text{ for all } g \text{ in group } G, \tag{A.14}$$

with M_G *the total imports of goods from group* G *and* $\bar{m} \equiv \{m_g\}_{g \in \mathcal{G}^{-T}}$ *the vector of imports associated with exogenous trade taxes.*

PROOF: Let $\hat{t}^* \equiv \{\hat{t}_G^*\}$ denote the vector of trade taxes that the government can freely impose across different groups of goods G. The same arguments as in the proof of Proposition 1 now imply

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

with $\tilde{M} \equiv \{\tilde{M}_G\}$ the vector of total imports from each group G and $\tilde{\bar{m}} \equiv \{\tilde{m}_g\}_{g \in \mathcal{G}^{-T}}$ the vector of imports of goods with fixed trade taxes, both expressed as a function of the freely chosen vector of trade taxes $\hat{t}$. Multiplying both sides by $(D_t \tilde{M})^{-1}$, we obtain (A.14). *Q.E.D.*

Negotiated Trade Taxes. Consider a variation of the environment of Section 2.1 in which Foreign comprises multiple countries indexed by i, each with many individuals indexed by n. Individuals choose their vector of net imports $m(i,n)$ in order to solve

$$\max_{m(i,n)} u(m(i,n); i, n) \tag{A.15}$$

$$\text{subject to: } p^w \cdot m(i,n) = 0.$$

Foreign's offer curve is such that Home's net imports $m \in \Omega(p^w, z)$ if and only if $m = -\sum_{i,n} m(i,n)$ with $m(i,n)$ that solves (A.15).[2] Because of trade negotiations, we assume that Pareto efficient trade taxes at Home now solve

$$\max_{t \in \mathcal{T}} \max_{\{u(n), u(i,n)\}} u(n_0) \tag{A.16}$$

$$\text{subject to: } u(n) \geq \underline{u}(n) \text{ for } n \neq n_0,$$

[2]The maximand $u(m(i,n); i, n)$ is what Dixit and Norman (1980) refer to as the "Meade utility function."

$$u(i,n) \geq \underline{u}(i,n) \text{ for all } i \text{and } n,$$
$$\{u(n), u(i,n)\} \in \tilde{\mathcal{U}}(t),$$

where $\tilde{\mathcal{U}}(t)$ denotes the set of domestic and foreign utilities attainable in a competitive equilibrium with trade taxes t. In this alternative environment, Proposition 1 extends as follows.

PROPOSITION A.4—Negotiated Trade Taxes: *Suppose that there are foreign individuals whose utility the Home government cares about, as summarized by equations* (A.15) *and* (A.16). *Then Pareto efficient trade taxes satisfy*

$$t_g^* = -\beta \cdot \frac{\partial(\omega - \bar{\omega})}{\partial m_g} - \sum_i [1 - \beta(i,n)] \left[m(i,n) \cdot \frac{\partial p^w}{\partial m_g} \right] + \epsilon \cdot \frac{\partial z}{\partial m_g} \text{ for all } g \in \mathcal{G}^T, \quad \text{(A.17)}$$

with $\beta(i,n) \equiv \lambda(i,n)/\bar{\lambda}$ *and* $\lambda(i,n)$ *the social marginal utility of income of individual* n *in country* i *(from Home's perspective).*

PROOF: The Lagrangian associated with (A.16) is

$$\mathcal{L} = u(c(n_0), z; n_0) + \sum_{n \neq n_0} \nu(n)[u(c(n), z; n) - \underline{u}(n)] + \sum_{i,n} \nu(i,n)[u(m(i,n); i, n) - \underline{u}(i,n)],$$

with $\nu(i,n) \geq 0$ the Lagrange multiplier associated with the utility constraint of individual n in country i. The first-order condition (A.1) in the proof of Proposition 1 therefore generalizes to

$$\sum_{n \in \mathcal{N}} \nu(n) du(n) + \sum_i \nu(i,n) du(i,n) = 0, \text{ for all } g \in \mathcal{G}^T. \quad \text{(A.18)}$$

Starting from (A.15) and invoking the Envelope Theorem, we get

$$du(i,n) = -\mu(i,n)[m(i,n) \cdot dp^w], \quad \text{(A.19)}$$

with $\mu(i,n) \geq 0$ the Lagrange multiplier associated with the foreign individual's budget constraint in (A.15). Starting from (A.18) and (A.19) and following the same steps as in the proof of Proposition 1, we then obtain (A.17), with $\lambda(i,n) \equiv \mu(i,n)\nu(i,n) \geq 0$ the social marginal utility of of individual n in country i (from Home's perspective). *Q.E.D.*

Imperfect Competition. Consider a variation of the environment of Section 2.1 with imperfect competition. To fix ideas, suppose that 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, as in Costinot and Werning (2019). 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 $\{Y(\sigma, f), C(\sigma, n)\}$ and a transfer $\tau(\sigma)$ such that the equilibrium conditions (i), (ii), (iii), (v), (vi), and (vii) in Definition 1 hold. Firm f solves

$$\max_{\sigma(f) \in \Sigma(f)} P(\sigma) \cdot Y(\sigma, f), \quad \text{(A.20)}$$

taking the correspondences of other firms $\{\sigma(f')\}_{f'\neq f}$ as given. Under these alternative assumptions about market structure, Proposition 1 extends as follows.

PROPOSITION A.5—Imperfect Competition: *Suppose that firms are imperfectly competitive, as described in equation (A.20). Then constrained Pareto efficient trade taxes satisfy*

$$t_g^* = -\beta \cdot \frac{\partial(\omega - \bar{\omega})}{\partial m_g} + m \cdot \frac{\partial p^w}{\partial m_g} + \epsilon^z \cdot \frac{\partial z}{\partial m_g} - \sum_{f\in\mathcal{F}} \epsilon^y(f) \cdot \frac{\partial y(f)}{\partial m_g} \text{ for all } g \in \mathcal{G}^T, \quad \text{(A.21)}$$

where $\epsilon^z \equiv \sum_{n\in\mathcal{N}} \beta(n) e_z(n)$ *denotes the social marginal cost of externalities and* $\epsilon^y(f) \equiv [\sum_{n\in\mathcal{N}} \beta(n)\phi(f,n)]p$ *denotes the social marginal cost of distortions in firm* f*'s output.*

PROOF: Compared to the proof of Proposition 1, equations (A.1) and (A.2) continue to hold. Given (A.20), however, equation (A.3) becomes

$$d\pi(f) = y(f) \cdot dp + p \cdot dy(f), \quad \text{(A.22)}$$

with $\pi(f)$ the equilibrium profits of firm f. Substituting (A.22) into (A.2), we then obtain

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

The same arguments as in the proof of Proposition 1 then implies (A.21). *Q.E.D.*

A.3. *An Example of Pareto Inefficient Trade Taxes*

In Section 2.3, we have argued that Pareto inefficient trade taxes may arise in dynamic environments where choices over today's trade policy may also affect the policy implemented tomorrow. We now formalize this idea in the context of a two-period example.

There are two periods, indexed by $T = 1$ or 2. Within each period, the environment is as described in Section 2.1 and the competitive equilibrium is as described in Section 2.2 . Across periods, the overall utility of an individual n with utility flow $u_1(n)$ in period 1 and utility flow $u_2(n)$ in period 2 is $u_1(n) + u_2(n)$. Technology and preferences are fixed over time, but trade taxes may vary. We let $t_T \equiv \{t_{g,T}\}$ denote the vector of trade taxes in period T and $\mathcal{U}(t_T)$ denote the set of utility profiles attainable in a competitive equilibrium with trade taxes t_T.

In period 1, the government chooses trade taxes t_1, but cannot commit to the future trade taxes t_2. Specifically, conditional on a vector of trade taxes t_1 from period 1, we assume that the government sets trade taxes in period 2 in order to solve

$$\begin{aligned} &\max_{t_2\in\mathcal{T}} \max_{\{u_2(n)\}} u_2(n_0) \\ &\text{subject to: } u_2(n) \geq \underline{u}(n, t_1) \text{ for } n \neq n_0, \\ &\{u_2(n)\} \in \mathcal{U}(t_2), \end{aligned}$$

Critically, t_1 may affect the reservation utility $\underline{u}(n, t_1)$ of different individuals in the period 2 problem. This captures in a reduced-form way the impact of period 1's policies on political forces and hence the government's incentives in period 2. For instance, t_1 may affect the size of different sectors and their political power, as in Acemoglu and Robinson (2001), or t_1 may affect voters' beliefs about a politician's type in period 1 and, in turn, the probability that a politician with different preferences may be elected and select policy in period 2, as in Coate and Morris (1995). For any given vector of trade taxes in period 1, we let $\mathcal{T}_2^*(t_1)$ denote the set of optimal trade taxes in period 2.

We are now ready to describe the choice of the government in period 1. We solve for a Subgame Perfect Nash Equilibrium (SPNE) in which the government in period 1 anticipates the government in period 2 to pick $t_2 \in \mathcal{T}_2^*(t_1)$. Hence the vector of trade taxes t_1^* chosen in period 1 solves

$$\begin{aligned} \max_{\{t_T\}\in\mathcal{T}} \max_{\{u_T(n)\}} & \sum_{T=1,2} u_T(n_0) \\ \text{subject to: } & \sum_{T=1,2} u_T(n) \geq \underline{u}(n) \text{ for } n \neq n_0, \\ & \{u_T(n)\} \in \mathcal{U}(t_T), \\ & t_2 \in \mathcal{T}_2^*(t_1). \end{aligned}$$

To facilitate the description of trade taxes in a SPNE, suppose that (i) for any vector of trade taxes t_T, there is a unique utility profile $\{u(n,t_T)\}$ attainable in a competitive equilibrium (i.e., $\mathcal{U}(t_T)$ is a singleton) and (ii) for any vector of trade taxes t_1 imposed in period 1, there is a unique vector of trade taxes $t_2^*(t_1)$ that solves the government's problem in period 2 (i.e., $\mathcal{T}_2^*(t_1)$ is a singleton). We can therefore directly express the necessary first-order conditions associated with the vector of trade taxes t_1^* chosen in period 1 as

$$\sum_{n\in\mathcal{N}} \nu(n) \left\{D_{t_1}[u(n,t_1^*)] + D_{t_1}[t_2^*(t_1^*)] D_{t_2}[u(n,t_2^*(t_1^*))]\right\} = 0.$$

The condition for Pareto efficiency of trade taxes in period 1 instead requires

$$\sum_{n\in\mathcal{N}} \nu(n) D_{t_1}[u(n,t_1^*)] = 0.$$

It follows that trade taxes chosen in period 1 are Pareto-inefficient if the two vectors, $D_{t_1}[u(n,t_1^*)]$ and $D_{t_1}[t_2^*(t_1^*)]D_{t_2}[u(n,t_2^*(t_1^*))]$, are not collinear.

APPENDIX B: DATA APPENDIX

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

B.1. *Data for Model Calibration*

We begin by describing the data sources and methodology that we adopt to measure the variables used to calibrate the model. All data is for the year 2017.

We define the set of domestic regions $\mathcal{R}_H$ as the 50 US states plus Washington, DC. The set of foreign countries $\mathcal{R}_F$ includes the top 100 US trade partners in 2017, plus the rest of the world treated as a single country. There are $|\mathcal{R}_H| = 51$ domestic regions and $|\mathcal{R}_F| = 101$ foreign countries.

Our sector classification contains 22 sectors. We consider 21 sectors in agriculture, oil, mining, and manufacturing that we define based on the intersection of NAICS-based codes in the 2017 BEA make-use tables and the 2017 Commodity Flow Survey (CFS): Agriculture (NAICS 11); Oil and gas (NAICS 211); Other mining (NAICS 212); Food and tobacco (NAICS 311); Textiles (NAICS 313); Apparel (NAICS 315); Wood products (NAICS 321); Paper and printing (NAICS 322-323); Oil and coal products (NAICS 324); Chemical products (NAICS 325); Plastic products (NAICS 326); Mineral products (NAICS 327); Primary metals (NAICS 331); Metal products (NAICS 332); Machinery (NAICS 333); Electronic products (NAICS 334); Electrical and appliances (NAICS 335); Motor vehicles (NAICS 3361); Other transportation equipment (NAICS 3364); Furniture (NAICS 337); and Miscellaneous manufacturing (NAICS 339). In addition, we have a single non-tradable, service sector containing all other NAICS sectors not listed above.

To define our product set $\mathcal{H} \equiv \cup_{s \in \mathcal{S}} \mathcal{H}_s$, we start from the 6-digit HS2017 classification, and drop products that the US did not export or import in 2017. We then use FGKK's crosswalk from 10-digit HS2017 products to 3-digit NAICS sectors to build our crosswalk from 6-digit HS2017 products to the sectors defined above. Specifically, for each 6-digit HS2017 product, we compute the share of trade (i.e., the sum of exports and imports) on each of our sectors using the trade flows of all 10-digit sub-products (of the given 6-digit HS) linked to the sector in FGKK's crosswalk. We then map the 6-digit HS2017 product to the sector in our classification with the highest trade share. This procedure implies that more than 90% of the 6-digit HS2017 products are mapped to a sector that accounts for at least 99% of the 10-digit sub-products' exports and imports. In 2017, there are 5,299 6-digit HS2017 products that have positive exports or imports.

We now describe how we build the variables used in calibration.

National Accounts. For each sector, we use the BEA's make-use tables (before redefinitions) to measure gross output Y_s^{NA}, intermediate spending I_{ks}^{NA}, final spending F_s^{NA}, exports Exp_s^{NA}, and imports Imp_s^{NA}. The make-use table contains information on production and purchases for 71 industries and 73 commodities. We first map output and spending from the commodity$\times$industry space to the industry$\times$industry space by assuming that each industry supplies the same bundle of commodities to all buyers and demands the same bundle of commodities from all sellers. We then use the fact that the BEA industries are based on NAICS codes to map each of them to one of our sectors. Finally, we obtain each sector-level variable by summing across the associated BEA industries.

International Trade and Tariffs. We use USA TRADE ONLINE to download international trade data from the US Census. First, we use data by origin of movement and state of destination to obtain the value of FOB exports (origin of movement) and CIF imports (state of destination) for each region r and 6-digit HS2017 product $h \in \mathcal{H}$, which we denote as $Exp^{\text{Census}}_{rih}$ and $Imp^{\text{Census}}_{irh}$, respectively.[3] Second, for each 6-digit HS2017 $h \in \mathcal{H}$ and foreign country $i \in \mathcal{R}_F$, we use HS District-level Data to measure t^{av}_{ih} as the ratio between the calculated duty and the FOB import value (summed over all 10-digit HS2017 subproducts of the 6-digit HS2017, and all countries in the RoW). Third, we re-scale imports and exports in each sector to be consistent with their values in the National Accounts. For every $h \in \mathcal{H}_s$ within each sector $s \in \mathcal{S}$ other than services, we construct

$$X^{M,F}_{rish} = Exp^{\text{Census}}_{rih} \frac{Exp^{\text{NA}}_s}{\sum\limits_{r \in \mathcal{R}_H, i \in \mathcal{R}_F, h \in \mathcal{H}_s} Exp^{\text{Census}}_{rih}}$$

and

$$X^{F}_{irsh} = (1 + t^{\text{av}}_{ih}) Imp^{\text{Census}}_{irh} \frac{Imp^{\text{NA}}_s}{\sum\limits_{r \in \mathcal{R}_H, i \in \mathcal{R}_F, h \in \mathcal{H}_s} (1 + t^{\text{av}}_{ih}) Imp^{\text{Census}}_{irh}}.$$

Regional Accounts. For each region, we use the BEA's Regional Accounts to measure GDP and employment in each sector by summing across industries associated with that sector (using the same mapping from BEA industries to our sector classification discussed above). We define N_{rs} as the measured employment in each region and sector. Our measure of GDP, Π_{rs}, corresponds to the variable implied by the BEA's regional accounts, but re-scaled to match national GDP in each sector; that is, $\Pi_{rs} = \Pi^{\text{RA}}_{rs} (\Pi^{\text{NA}}_s / \sum_{r \in \mathcal{R}_H} \Pi^{\text{RA}}_{rs})$ where Π^{RA}_{rs} is the GDP reported in the Regional Accounts for sector s and region r, and $\Pi^{\text{NA}}_s = Y_s - \sum_{k \in \mathcal{S}} I^{\text{NA}}_{ks}$ is the value-added of sector s in the National Accounts.[4]

For each region-sector, we impute gross output as the maximum between its exports, $X^{M,F}_{rs} = \sum_{i \in \mathcal{R}_F} \sum_{h \in \mathcal{H}_s} X^{M,F}_{rish}$, and its GDP-implied revenue, $\Pi_{rs}/(1 - \alpha_s)$:

$$Y_{rs} = \max \left\{ \Pi_{rs}/(1 - \alpha_s), X^{M,F}_{rs} \right\}.$$

We note that this procedure guarantees that the model matches observed GDP and employment reported in the BEA for almost all region-sector pairs in the United States.[5]

Domestic Shipments. We use the microdata of the 2017 CFS to measure region-to-region domestic shipments for each sector. We start by mapping the NAICS-based CFS classification to our sector classification. We then obtain sectoral bilateral shipments, X^{CFS}_{ors}, by summing the

[3] A challenge with this data on international trade by domestic region is that exports are identified by the region in which their journey to port begins, which in some cases may differ from the region in which they were produced (and analogously for imports). However, the domestic shipments data described below should track the domestic flow between the region of production and the region of shipment for exports, so that we still (indirectly) attribute exports to their producing regions.

[4] For each sector, aggregate GDP from the Regional and National Accounts are very close; on average across sectors, the sum of regional GDP is 99.4% of the national GDP.

[5] The only failure occurs when observed exports $X^{M,F}_{rs}$ exceed $\Pi_{rs}/(1 - \alpha_s)$, in which case our model implies a region-sector GDP that is higher than the GDP reported in the BEA. Reassuringly, this happens for less than 3% of region-sector pairs, with a total excess amount that is less than 0.2% of US GDP.

value of shipments in sector s from region o to region r, while adjusting for sampling weights. For the subset of our sectors that are either equal to a CFS sector or the sum of multiple CFS sectors, we define bilateral domestic flows as

$$X^H_{ors} = x^{\text{CFS}}_{ors}(Y_{os} - X^{M,F}_{os}) \quad \text{with} \quad x^{\text{CFS}}_{ors} \equiv \frac{X^{\text{CFS}}_{ors}}{\sum_{d\in\mathcal{R}_H} X^{\text{CFS}}_{ods}}.$$

We now turn to the four tradable sectors without an analog in the CFS. Two sectors, Motor vehicles (NAICS 3361) and Other transportation equipment (NAICS 3364), are associated with the same sector in the CFS (Transportation Equipment Manufacturing, NAICS 336). For them, we compute bilateral domestic flows as $X^H_{ors} = x^{\text{CFS}}_{or336}(Y_{os} - X^{M,F}_{os})$, restricting the share of r in o's domestic shipments in each of the two sectors in our classification to be the same as that of their parent sector in the CFS. In addition, the CFS does not report domestic shipments for two of our sectors: Agriculture (NAICS 11) and Oil and gas (NAICS 211). For them, we assume that the share of r in o's domestic shipments is the same as that of the average shipment in the CFS, $X^H_{ors} = x^{\text{CFS}}_{or}(Y_{os} - X^{M,F}_{os})$ with $x^{\text{CFS}}_{or} \equiv X^{\text{CFS}}_{or} / \sum_{d\in\mathcal{R}_H} X^{\text{CFS}}_{od}$ and X^{CFS}_{or} the value of all shipments from o to r in the CFS. By construction, our procedure guarantees that, for each region-sector pair, gross output is equal to the sum of observed trade flows to all foreign and domestic regions.

Regional spending. Given international and domestic shipments, each region r's total spending on goods of sector s is equal to $X_{rs} = \sum_{h\in\mathcal{H}_s}\sum_{i\in\mathcal{R}_F} X^F_{irsh} + \sum_{o\in\mathcal{R}_H} X^H_{ors}$.

B.2. *Additional Data for Estimation*

Foreign Import Tariffs. The model validation presented in Section 3.5 relies on US import tariff changes implemented by the Trump administration in 2018-2019, as well as the retaliatory tariffs applied by US trading partners during the same period. Our measure of the US import tariff changes is the difference between 2019 and 2017 in the ad-valorem equivalent tariff applied by the US on each of the 6-digit HS2017 products and foreign countries that we described in Section 3.3 and Appendix B.1. FGKK's replication package is our source for data on the retaliatory tariff changes applied by US trading partners on different 6-digit HS2017 products during the US-China trade war.

Non-Tariff Measures. Our main data source regarding non-tariff measures (NTMs) is UNCTAD TRAINS. We use the bulk download tool to obtain data on the NTMs that the US imposed in 2017 on each 6-digit HS product and foreign country. The data set classifies US NTMs into five categories: (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." We use this data to create a dummy variable for each category that is equal to one for an origin-product pair in our sample if and only if the associated 6-digit HS and foreign country were subject to at least one NTM in 2017.

We complement this dataset with information on the anti-dumping and countervailing measures that the US had in place in 2017. Our main source is the World Bank Temporary Trade Barriers Database (Bown et al., 2020), which reports the countries, products and years covered by each case that resulted in the US implementing anti-dumping and countervailing measures.[6] Since the data is based on the HS classification of the case's year, we use HS classification crosswalks to link 6-digit HS2017 products to the cases since 1996 that are still in place in 2017. We then create a dummy that is equal to one for an origin-product pair in our sample if and only if the associated 6-digit HS and foreign country were subject to at least one anti-dumping or countervailing measure in 2017. For each such origin-product pair, we also compute an estimate of the average tariff rate inclusive of anti-dumping and countervailing duties. We start by computing the average anti-dumping and countervailing duty rate applied to targeted firms across all cases associated with imports of that product from that origin that are still in force in 2017. We then add to this rate the baseline tariff rate that the United States applied to imports of that product from that origin in 2017.

Domestic Production Subsidies. Our approach to obtaining data on production subsidies draws on that used by Ferrari and Ossa (2023). We primarily use data from the Upjohn Institute's Panel Database on Business Incentives (Bartik, 2017), which is available for 32 states, comprising a collective 91% of US GDP in 2017. Following Ferrari and Ossa (2023), we supplement this source with the *New York Times*' Business Incentive Database (Story et al., 2016) for the remaining 18 states. In addition, we use the Environmental Working Group's Farm Subsidy Database (Environmental Working Group, 2025) for the Agriculture sector, since this is omitted from the two previous databases.

The Upjohn database aims to calculate the (annualized value of the) "standard deal" of state and local government incentive payments that would be available to a representative firm establishing a new location in a given state and sector in the year 2015.[7] This value is expressed relative to the (annualized value of the) value-added produced by such a firm. We use each state-sector's gross output to value-added ratio (based on the production data described above) in order to convert the incentives reported by Upjohn as a share of gross output. Following again Ferrari and Ossa (2023), we treat these as the ad-valorem equivalent of s^y in our model. Because the Upjohn database does not cover the Real Estate, Oil & Gas, and Other Mining sectors, we assign each state's average reported subsidy rate to these three sectors.

The *New York Times* database differs from the Upjohn database in several respects.[8] First, it reports the total amount of incentives paid out to firms (by state and local governments) in any given state in a given year, rather than an estimate of the annualized value of incentives for a firm starting out in 2015. Second, the latest available year in the *New York Times* database is 2012. For these reasons, like Ferrari and Ossa (2023), we re-scale all values in the *New York Times* database by the ratio of total annualized implied payouts in the Upjohn database to total subsidy payouts (among the 32 Upjohn states) in the *New York Times* database.[9] We then apply these adjusted *New York Times* values to the 18 states not available in Upjohn (and apply them to all sectors other than Agriculture within these states), converting them into implied subsidy rates by dividing by total state gross output (among all sectors but Agriculture), as above.

Finally, the Environmental Working Group (EWG) database reports total subsidies paid to the Agriculture sector within each state in 2017. In contrast to the Upjohn and *New York Times* databases, this source tracks subsidies provided by the federal government (rather than state and local ones), but this is appropriate given the nature of agricultural subsidy programs which

[6]We thank Aksel Erbahar for his assistance in working with this dataset.

[7]Specifically, we use the "firm age weighting" in Upjohn to construct annualized values.

[8]We thank Ferrari and Ossa (2023) for sharing their web-scraped version of the *New York Times* database.

[9]This involves first converting the Upjohn subsidy rates, which are in terms of annual payouts per unit value-added, into total annual payouts by multiplying by the total value-added within each state-sector.

are primarily set at the federal level. We divide the EWG subsidy payments by the state's agricultural gross output in 2017 to obtain state-specific ad-valorem subsidies for this sector.

Marginal Income Tax Rates. We download individual-level data from the 2017 ACS from IPUMS USA. We start by building a mapping from the ACS NAICS-based industry codes (INDNAICS) to our sector classification. We use this mapping to assign employed individuals to a region-sector pair based on their sector of employment and region of residence. We then compute each individual's marginal wage and salary income tax rate (federal plus state) by entering ACS variables into the NBER's Tax Sim 35 tax calculator, including information on wage and salary, business and farm, self-employment, investment, pension, social security, and welfare income, state of residence, age, marital status and spousal income, dependents, rent, and childcare expenses. Next, we average these marginal rates across individuals within each region-sector pair, weighting by ACS person weight and by wage and salary income.[10] This is our measure of the average marginal tax on labor income for each region-sector pair. To obtain our measure of the average marginal tax on total income generated by each region-sector pair, we compute the weighted average of the pair's labor income tax and the capital income tax rate of 15%, weighting the former by the sector's labor share of value added. We obtain labor shares of value added from the 2017 BEA use table.

Unrestricted Tariffs. We classify the tariff on a product from a given origin as unrestricted if it satisfies one of the following two conditions: (i) it is associated with a country that is not a WTO member, or (ii) it is associated with a 6-digit HS product subject to tariff overhang and a country that is a WTO member and does not have a PTA with the United States. We define a 6-digit HS product as subject to tariff overhang if all of its 8-digit sub-products satisfy two conditions: (i) all tariffs are ad-valorem, and (ii) the MFN applied tariff is below its WTO negotiated bound. We proceed as follows to build a dummy for whether the 8-digit HS product has a MFN applied tariff below its WTO negotiated bound. We first use the 2017 Annual Tariff Data from the USITC to measure the MFN ad-valorem import tariff of 8-digit HS2012 products. We then use the WTO Consolidated Tariff Schedules Database (available at WTO Tariff Analysis Online) to compute the negotiated bound on ad-valorem tariffs of 8-digit HS2007 products. We use the USITC crosswalk to convert both datasets to the 8-digit HS2017 classification. We only consider in our analysis the set of 6-digit HS2017 products for which all 8-digit HS2017 sub-products can be uniquely mapped to a tariff line in the USITC and WTO datasets.

Demographic Composition of Employment. We download individual-level data from the 2017 ACS from IPUMS USA. We start by building a mapping from the ACS NAICS-based industry codes (INDNAICS) to our sector classification. We use this mapping to assign employed individuals to a region-sector pair based on their sector of employment and region of residence. We also assign each employed individual to one out of eight demographic groups based on the combinations of sex (male or female), race (white or non-white), and education (at least 4 years of college or less than 4 years of college). Finally, for each region-sector pair, we use sampling weights to compute the distribution of employment across the eight demographic groups.

Swing States. Our source is the database of U.S. presidential elections from the MIT Election Data and Science Lab. For each state, we compute the average share of votes for the

[10]For less than 2% of region-sector pairs, the 2017 ACS contains no observations. We impute marginal rates for these missing region-sector pairs as the predicted values of a regression of marginal rates on sector and region indicator variables.

Republican and Democratic candidates in all presidential elections between 2000 and 2016. We define as swing states those with a voting margin below 5% such that vote $\text{margin}_r \equiv |\text{Republican avg. vote share}_r - \text{Democratic avg. vote share}_r|$. According to this definition, the swing states are: Colorado, Florida, Iowa, Ohio, Nevada, New Hampshire, Pennsylvania, Virginia, and Wisconsin.

Lobbying Spending. Our source of lobby spending data is LobbyView (Kim, 2018). We use the report-level database to obtain all quarterly report fillings between 2000 and 2016. We match each report to one sector in our classification using the NAICS industry of the report's client (available in LobbyView's client-level database). We also obtain information on the lobbying issues of each report from the issue-level database. We define reports for trade-related issues as those about domestic/international trade ("TRD") or miscellaneous tariff bills ("TAR"). Finally, for each sector, we compute the average annual amount of lobbying spending between 2000 and 2016.

APPENDIX C: MODEL APPENDIX

Section C.1 characterizes the competitive equilibrium of the parametric model introduced in Section 3 , and Section C.2 describes our calibration procedure for the model's parameters.

C.1. *Competitive equilibrium*

Prices. For each domestic origin $r \in \mathcal{R}_H$, destination $d \in \mathcal{R}$, and product $h \in \mathcal{H}_s$ from sector $s \in \mathcal{S}$, equations (11)-(12) imply that the domestic price p_{rdh} is equal to

$$p_{rdh} = (\theta_{rds})^{-1} p_{rs}, \tag{C.1}$$

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

$$P_{rk} = \left[\sum_{c=H,F} \sum_{v \in \mathcal{H}_k} \sum_{o \in \mathcal{R}_c} \theta^c_{orkv} [p_{orv}]^{1-\sigma} \right]^{\frac{1}{1-\sigma}}. \tag{C.3}$$

Since there are no export taxes at Home, non-arbitrage further implies that if $d \in \mathcal{R}_F$, then

$$p_{rdh} = p^{M,F}_{rdh}. \tag{C.4}$$

Finally, for each foreign origin $i \in \mathcal{R}_F$, domestic destination $d \in \mathcal{R}_H$, and product $h \in \mathcal{H}_s$ from sector $s \in \mathcal{S}$, non-arbitrage implies

$$p_{idh} = t_{ih} + p^{X,F}_{irh}. \tag{C.5}$$

Bilateral Trade Flows. The expressions for prices in (C.1)-(C.3) and the expressions for technology and preferences in (11)-(12) and (13)-(14) imply that the (tariff-inclusive) spending in domestic region $r \in \mathcal{R}_H$ on product $h \in \mathcal{H}_s$ from foreign country $i \in \mathcal{R}_F$ is

$$X^F_{irsh} = \frac{\theta^F_{irsh} [p_{irh}]^{1-\sigma}}{[P_{rs}]^{1-\sigma}} X_{rs}, \tag{C.6}$$

where X_{rs} is total expenditure in region r on sector s. Similarly, spending in region r on all products of sector $s \in \mathcal{S}$ from domestic region $o \in \mathcal{R}_H$ is

$$X^H_{ors} = \frac{\sum_{h \in \mathcal{H}_s} \theta^H_{orsh} [p_{os}]^{1-\sigma}}{[P_{rs}]^{1-\sigma}} X_{rs}. \tag{C.7}$$

Input Demand. The problem of the representative producer f that produces $h \in \mathcal{H}_s$ in $r \in \mathcal{R}_H$ to sell in $d \in \mathcal{R}$ is

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

This implies $w_{rs} \ell_{rs}(f) = \alpha_s Y_{rdh}$ and $P_{rk} Q_{rk}(f) = \alpha_{ks} Y_{rdh}$, where $Y_{rdh} = p_{rdh} q(f)$ 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

$$W_{rs} = \alpha_s Y_{rs} \quad \text{and} \quad I_{rks} = \alpha_{ks} Y_{rs}, \tag{C.8}$$

where $W_{rs} \equiv w_{rs} N_{rs}$ and $Y_{rs} \equiv \sum_{d \in \mathcal{R}, h \in \mathcal{H}_s} Y_{rdh}$ are the value added and revenue of all firms in domestic region r and sector s, and I_{rks} is the expenditure of all such firms on intermediate inputs from sector k.

Substituting in for $Q_{rk}(f)$ in each firm's production function, we obtain the revenue in each region-sector:

$$Y_{rs} = \phi_{rs} N_{rs} (p_{rs})^{1/\alpha_s} \prod_{k \in \mathcal{S}} [\alpha_{ks}/P_{rk}]^{\alpha_{ks}/\alpha_s}. \tag{C.9}$$

Final Demand. Equation (13) implies that final expenditure in region r on sector s is

$$F_{rs} = P_{rs} C_{rs} = \gamma_s F_r, \tag{C.10}$$

where F_r denotes aggregate final spending in r, which is equal to r's aggregate income,

$$F_r = \sum_{s \in \mathcal{S}} W_{rs} + \sum_{s \in \mathcal{S}} N_{rs} \tau \quad \text{with} \quad \tau = \frac{1}{N} \sum_{i \in \mathcal{R}_F} \sum_{r \in \mathcal{R}_H} \sum_{s \in \mathcal{S}} \sum_{h \in \mathcal{H}_s} \frac{t_{ih}}{p_{irh}} X^F_{irsh}. \tag{C.11}$$

The consumption price index is given by

$$P^C_r = \prod_{k \in \mathcal{S}} (P_{rk})^{\gamma_k}. \tag{C.12}$$

Market Clearing. Total spending of each region r on sector s is

$$X_{rs} = \xi_{rs} + \gamma_s \left(\sum_{k \in \mathcal{S}} \alpha_k Y_{rk} + N_r \tau \right) + \sum_{k \in \mathcal{S}} \alpha_{sk} Y_{rk}, \tag{C.13}$$

where $N_r \equiv \sum_s N_{rs}$. Domestic demand for goods of sector s produced by region $r \in \mathcal{R}_H$ is

$$D^H_{rs} = \sum_{d \in \mathcal{R}_H} X^H_{rds}. \tag{C.14}$$

Using equations (16), (C.1), and (C.4), foreign country i's expenditure $X^{M,F}_{ris} = \sum_{h \in \mathcal{H}_s} p^{M,F}_{rih} q^{M,F}_{rih}$ on goods produced by domestic region r in sector s is

$$X^{M,F}_{ris} = (p_{rs})^{1-1/\psi^{M,F}} (\theta_{ris})^{-(1-1/\psi^{M,F})} \sum_{h \in \mathcal{H}_s} (\theta^{M,F}_{rih})^{1/\psi^{M,F}}.$$

Thus total foreign demand faced by region r in sector s, $D^F_{rs} \equiv \sum_{i \in \mathcal{R}_F} X^{M,F}_{ris}$, is given by

$$D^F_{rs} = \delta_{rs} (p_{rs})^{1-1/\psi^{M,F}} \quad \text{where} \quad \delta_{rs} \equiv \sum_{i \in \mathcal{R}_F} (\theta_{ris})^{-(1-1/\psi^{M,F})} \sum_{h \in \mathcal{H}_s} (\theta^{M,F}_{rih})^{1/\psi^{M,F}}. \tag{C.15}$$

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

$$Y_{rs} = D^F_{rs} + D^H_{rs}. \tag{C.16}$$

By equations (15) and (C.5), market clearing for imports requires that for all $i \in \mathcal{R}_F$, $r \in \mathcal{R}_H$, and $h \in \mathcal{H}$,

$$(p_{irh})^{1+\psi^{X,F}} = t_{ih} (p_{irh})^{\psi^{X,F}} + \theta^{X,F}_{irh} (X^F_{irsh})^{\psi^{X,F}} \tag{C.17}$$

with X^F_{irsh} given by equation (C.6).

C.2. *Calibration*

We now show how we calibrate $\{\alpha_s, \alpha_{ks}, \gamma_s, \xi_{rs}, \theta_{rds}, \theta^c_{orsh}, \theta^{X,F}_{irh}, \theta^{M,F}_{rih}, \phi_{rs}, N_{rs}\}$. As a first step, we normalize all foreign export prices to one, $p^{X,F}_{irh} = 1$, which implies that $t_{ih} = p^{X,F}_{irh} t^{\text{av}}_{ih} = t^{\text{av}}_{ih}$. We also normalize wages and the prices of domestically produced goods to one: $w_{rs} = 1$ and $p_{rdh} = (\theta_{rds})^{-1} p_{rs} = 1$. From (C.1)-(C.3), this implies that

$$P_{rk} = \left[\sum_{v \in \mathcal{H}_k} \sum_{o \in \mathcal{R}_H} \theta^H_{orkv} + \sum_{v \in \mathcal{H}_k} \sum_{o \in \mathcal{R}_F} \theta^F_{orkv} [1 + t^{\text{av}}_{ov}]^{1-\sigma} \right]^{\frac{1}{1-\sigma}}. \tag{C.18}$$

Lower-nest Technology and Preference Parameters: $\{\theta^c_{orsh}\}$. Under our price normalization, (C.6) implies

$$\theta^F_{irsh} = \frac{X^F_{irsh}}{X_{rs}} \left[\frac{P_{rs}}{1 + t^{\text{av}}_{ih}} \right]^{1-\sigma},$$

where X^F_{irsh} is the (tariff-inclusive) value of imports of product $h \in \mathcal{H}_s$ from country i by region r, X_{rs} is the aggregate spending on sector s in region r , and P_{rk} is given by (C.18).

Similarly, (C.7) implies that $\sum_{v \in \mathcal{H}_k} \theta^H_{orkv} = (X^H_{ors}/X_{rs})[P_{rs}]^{1-\sigma}$. Given that $\theta^H_{orkv} = \bar{\theta}^H_{ork}$ for all $v \in \mathcal{H}_k$,

$$\theta^H_{orkv} = \bar{\theta}^H_{ork} = \frac{X^H_{ors}}{X_{rs}} [P_{rs}]^{1-\sigma} \Big/ |\mathcal{H}_k|.$$

Upper-nest Technology Parameters: $\{\alpha_{ks}, \alpha_s, \theta_{rds}\}$. Since (C.8) holds for all domestic regions, we set α_{ks} equal to sector s's national spending share on inputs from sector k:

$$\alpha_{ks} = \frac{I^{\text{NA}}_{ks}}{Y^{\text{NA}}_s}.$$

Using (C.8), we then set the value-added share α_s equal to:

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

Finally, under our price normalization, (C.1) and (C.2) imply

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

Upper-nest Preference Parameters: $\{\gamma_s\}$. Since (C.10) holds for all domestic regions, we set γ_s equal to the share of s in national final spending:

$$\gamma_s = \frac{F^{\text{NA}}_s}{\sum_k F^{\text{NA}}_k}.$$

Foreign Supply and Demand Shifters: $\{\theta^{X,F}_{irh}, \theta^{M,F}_{rih}\}$. Under our price normalization, (15) and (16) imply

$$\theta^{X,F}_{irh} = (1 + t^{\text{av}}_{ih})^{\psi^{X,F}} (X^F_{irsh})^{-\psi^{X,F}},$$

$$\theta_{rih}^{M,F} = (X_{rish}^{M,F})^{\psi^{M,F}},$$

with $X_{rish}^{M,F}$ the value of exports of product h of sector s from region r to country i.

Residual Spending: $\{\xi_{rs}\}$. We first compute lump-sum transfers using (C.11):

$$\tau = \frac{1}{N} \sum_{i \in \mathcal{R}_F} \sum_{r \in \mathcal{R}_H} \sum_{s \in \mathcal{S}} \sum_{h \in \mathcal{H}_s} \frac{t_{ih}^{\text{av}}}{1 + t_{ih}^{\text{av}}} X_{irsh}^{F}.$$

Finally, given X_{rs}, Y_{rs}, and $N_r\tau$, we use (C.13) to solve for ξ_{rs} as:

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

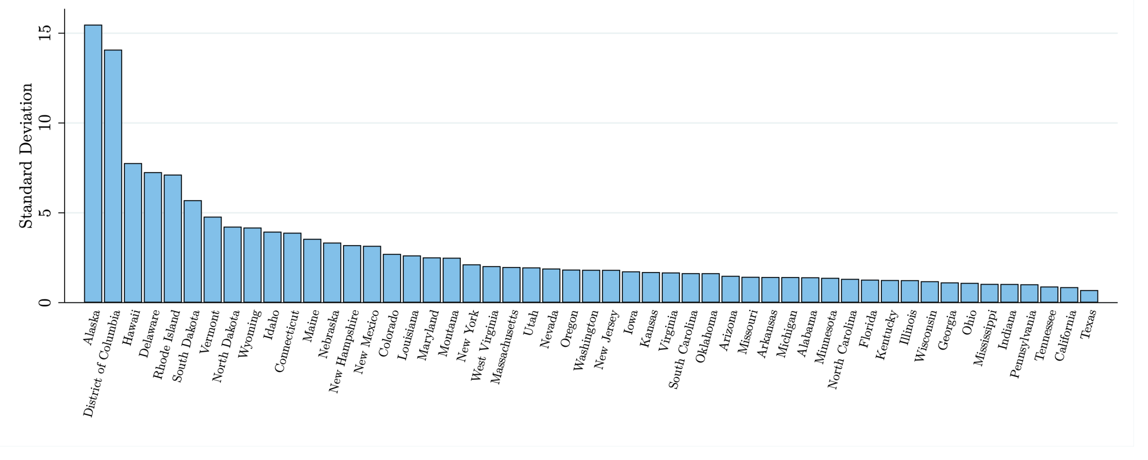
Employment and labor endowments: $\{\phi_{rs}, N_{rs}\}$ We set region-sector employment to the values in the BEA's regional accounts, $N_{rs} = N_{rs}^{\text{RA}}$. We then set region-sector labor endowments per worker, ϕ_{rs}, to match value-added in each region-sector. Given our wage normalization and equation (C.8), this is equivalent to setting ϕ_{rs} such that

$$\phi_{rs} N_{rs} = \alpha_s Y_{rs}.$$

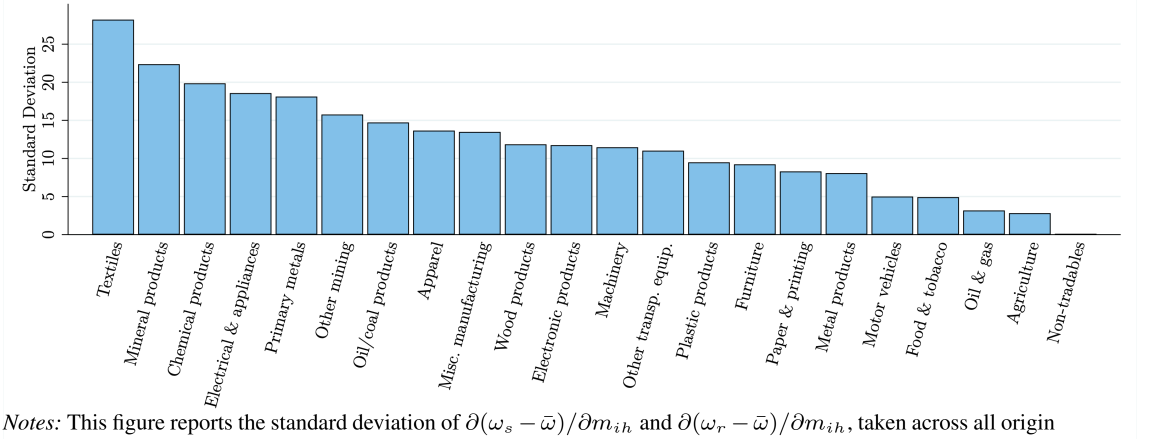
APPENDIX D: ESTIMATION APPENDIX

FIGURE D.1.—Standard deviation of sensitivity of real earnings to different imports

(a) Region

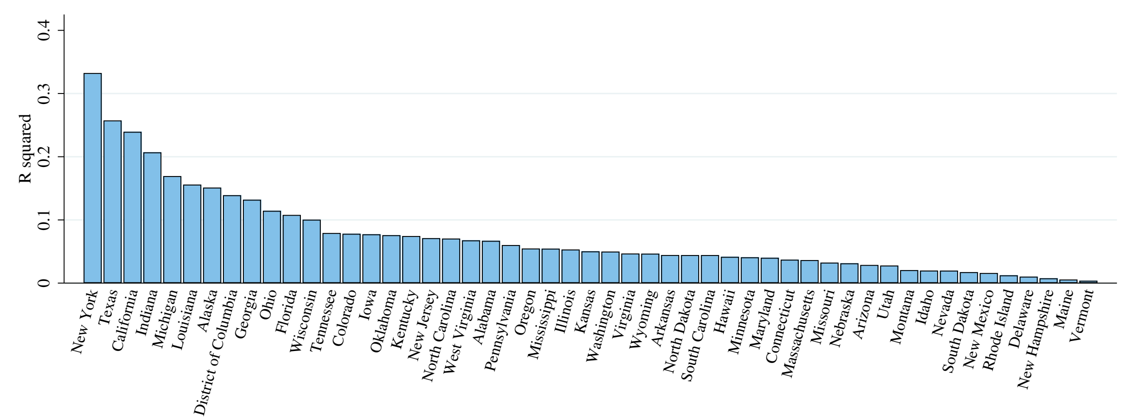


(b) Sector



Notes: This figure reports the standard deviation of $\partial(\omega_s - \bar{\omega})/\partial m_{ih}$ and $\partial(\omega_r - \bar{\omega})/\partial m_{ih}$, taken across all origin countries i and products h in our baseline sample, separately for each sector and region.

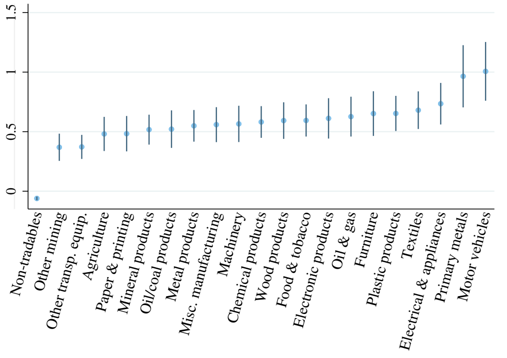
FIGURE D.2.—R^2 of regression for each region r of $\partial(\omega_r - \bar{\omega})/\partial m_{ih}$ on$\{\partial(\omega_s - \bar{\omega})/\partial m_{ih}\}_{s\in\mathcal{S}}$



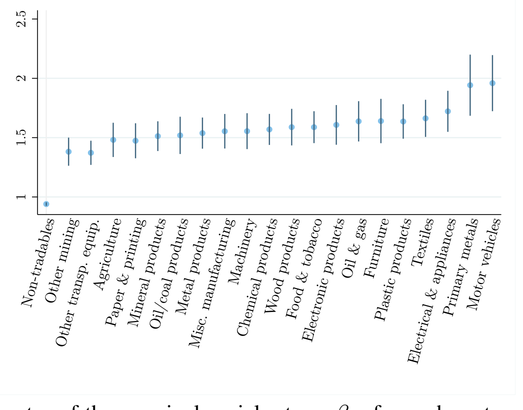
Notes: This figure reports the R^2 from a regression, estimated separately for each region r, of $\partial(\omega_r - \bar{\omega})/\partial m_{ih}$ on the set of 22 sectoral variables $\{\partial(\omega_s - \bar{\omega})/\partial m_{ih}\}_{s\in\mathcal{S}}$ and a constant in our baseline sample of origin countries i and products h.

FIGURE D.3.—Estimates of sector-based welfare weights (omitting Apparel sector)

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



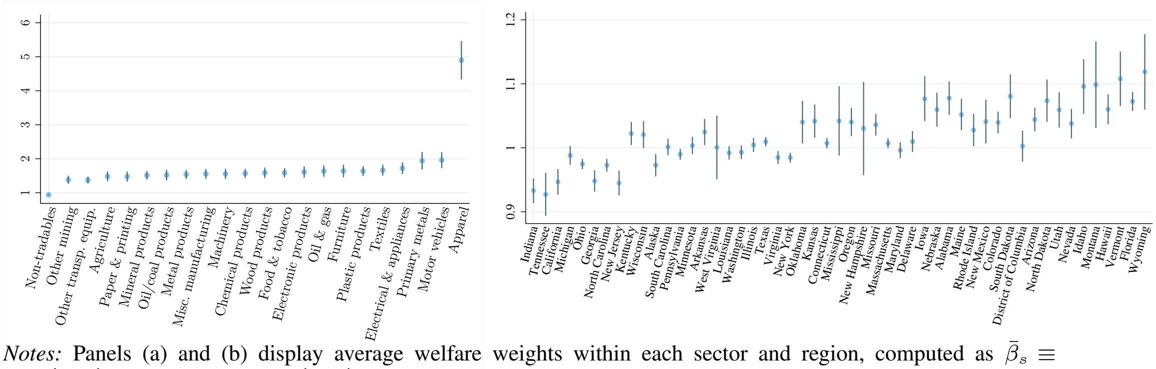
(b) $\bar{\beta}_s$ estimates



Notes: Panel (a) displays estimates of the marginal social return, β_s, for each sector s, as obtained from equation (19) and normalized such that the mean of $\hat{\beta}_s$ across s is zero. Panel (b) displays estimates of average welfare weights computed as $\bar{\beta}_s \equiv \sum_r \left(\frac{N_{sr}}{N_s}\right) \hat{\beta}_{rs}$. Blue dots correspond to point estimates and bars denote 95% confidence intervals. In both cases, the Apparel sector is omitted for clarity. Standard errors are clustered at the product-level.

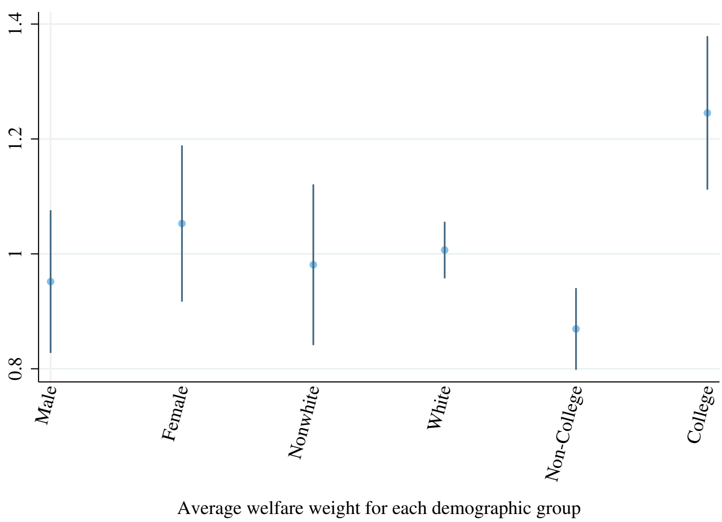
FIGURE D.4.—Estimates of average welfare weights across sectors and regions

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



Notes: Panels (a) and (b) display average welfare weights within each sector and region, computed as $\bar{\beta}_s \equiv \sum_r \left(\frac{N_{sr}}{N_s}\right) \hat{\beta}_{rs}$ and $\bar{\beta}_r \equiv \sum_s \left(\frac{N_{sr}}{N_r}\right) \hat{\beta}_{rs}$, respectively. Blue dots correspond to point estimates and bars denote 95% confidence intervals. Standard errors are clustered at the product-level.

FIGURE D.5.—Estimates of average welfare weights across other demographic groups



Notes: This figure displays the estimated values of the average welfare weight of each demographic group d, computed as $\bar{\beta}_d \equiv \sum_{r,s} \left(\frac{N_{rsd}}{N_d}\right) \hat{\beta}_{rsd}$.

APPENDIX E: NUMERICAL ALGORITHM FOR EQUILIBRIUM COMPUTATION

This section describes the algorithm that we use to compute equilibria with zero tariffs in Section 4.3, in order to construct instrumental variables, as well as equilibria without redistributive trade protection in Section 5. Given the multiplicative structure of the model, it is convenient to work with ad-valorem tariffs $\{t^{\text{av}}_{ih}\}$. Formally, the equilibrium conditions are those described in Appendix C, except for the two equations (C.11) and (C.17) in which specific tariffs enter explicitly, which we write as

$$\tau = \frac{1}{N}\sum_{i\in\mathcal{R}_F}\sum_{r\in\mathcal{R}_H}\sum_{s\in\mathcal{S}}\sum_{h\in\mathcal{H}_s}\frac{t^{\text{av}}_{ih}}{1+t^{\text{av}}_{ih}}X^F_{irsh}, \tag{E.1}$$

$$(p_{irh})^{1+\psi^{X,F}} = \frac{t^{\text{av}}_{ih}}{1+t^{\text{av}}_{ih}}(p_{irh})^{1+\psi^{X,F}} + \theta^{X,F}_{irh}(X^F_{irh})^{\psi^{X,F}}. \tag{E.2}$$

The algorithm solves for the equilibrium conditional on arbitrary ad-valorem tariffs $\{\tilde{t}^{\text{av}}_{ih}\}$ as well as the calibrated values of $\{\alpha_s, \alpha_{ks}, \gamma_s, \xi_{rs}, \theta_{rds}, \theta^c_{orsh}, \theta^{X,F}_{irh}, \theta^{M,F}_{rih}, L_{rs} \equiv \phi_{rs}N_{rs}, N_{rs}\}$ and $\{\sigma, \psi^{X,F}, \psi^{M,F}\}$.[11] For the counterfactual with zero tariffs, we set $\tilde{t}^{\text{av}}_{ih} = 0$. For the counterfactual without redistributive trade protection, we set $\tilde{t}^{\text{av}}_{ih} = t'_{ih}$, where t'_{ih} is described in equation (20).[12]

E.1. *Home and Foreign Price Indices and Expenditures*

In what follows, it will be convenient to work with sub-price indices for the Home and Foreign varieties within each sector purchased by each region. Concretely, equations (C.1)-(C.3) imply

$$p_{rs} = [\alpha_s]^{-\alpha_s}[w_{rs}]^{\alpha_s}\prod_{k\in S}[\alpha_{ks}]^{-\alpha_{ks}}[P_{rk}]^{\alpha_{ks}}, \tag{E.3}$$

$$P_{rk} = \left[\sum_{c=H,F}\theta^c_{rk}[P^c_{rk}]^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \tag{E.4}$$

$$P^H_{rk} = \left[\sum_{o\in\mathcal{R}_H}\tilde{\theta}^H_{ork}[p_{ok}]^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{E.5}$$

$$P^F_{rk} = \left[\sum_{v\in\mathcal{H}_k}\sum_{o\in\mathcal{R}_F}\tilde{\theta}^F_{orkv}[p_{orv}]^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{E.6}$$

where $\theta^c_{rk} \equiv \sum_{v\in\mathcal{H}_k}\sum_{o\in\mathcal{R}_c}\theta^c_{orkv}$, $\tilde{\theta}^H_{ork} \equiv \sum_{v\in\mathcal{H}_k}\theta^H_{orkv}/\theta^H_{rk}/(\theta_{orv})^{1-\sigma}$, and $\tilde{\theta}^F_{orkv} \equiv \theta^F_{orkv}/\theta^F_{rk}$. These definitions and equations (C.6)-(C.7) allow us to express expenditures as

$$X^F_{irsh} = \frac{\tilde{\theta}^F_{irsh}[p_{irh}]^{1-\sigma}}{[P^F_{rs}]^{1-\sigma}}X^F_{rs} \quad \text{and} \quad X^F_{rs} = \frac{\theta^F_{rs}[P^F_{rs}]^{1-\sigma}}{[P_{rs}]^{1-\sigma}}X_{rs}, \tag{E.7}$$

[11] In what follows, we work with L_{rs} instead of ϕ_{rs} as a way to handle cases in which $N_{rs} = 0$ but $\phi_{rs}N_{rs} > 0$.

[12] Since we have normalized import prices to one in the initial equilibrium and set $\psi^{X,F} = 0$, we note that the world prices of Home's imports in the counterfactual equilibrium without redistribution still satisfy $p^{X,F}_{irh} \equiv 1$. So specific and ad-valorem tariffs are equivalent in the counterfactual equilibrium.

$$X_{ors}^H = \frac{\tilde{\theta}_{ors}^H [p_{os}]^{1-\sigma}}{[P_{rs}^H]^{1-\sigma}} X_{rs}^H \quad \text{and} \quad X_{rs}^H = \frac{\theta_{rs}^H [P_{rs}^H]^{1-\sigma}}{[P_{rs}]^{1-\sigma}} X_{rs}. \tag{E.8}$$

E.2. *Solving for Domestic Demand*

A key step in characterizing equilibrium outcomes is to solve for the domestic spending $\{X_{rs}\}$ as a function of $\{p_{rs}\}$ and $\{P_{rs}^F\}$. 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_{rs} and P_{rs}^F and X_{rs}. From the expressions above and in Appendix C, we get that

$$X_{irsh}^F = \frac{\tilde{\theta}_{irsh}^F [p_{irh}]^{1-\sigma}}{[P_{rs}^F]^{1-\sigma}} X_{rs}^F,$$

$$p_{irh} = \left[\theta_{irh}^{X,F}(1+\tilde{t}_{ih}^{\text{av}})\right]^{\frac{1}{1+\psi^{X,F}}} \left(X_{irsh}^F\right)^{\frac{\psi^{X,F}}{1+\psi^{X,F}}}. \tag{E.9}$$

Thus,

$$p_{irs} = \left[\theta_{irh}^{X,F}(1+\tilde{t}_{ih}^{\text{av}})\right]^{\frac{1}{1+\psi^{X,F}\sigma}} \left(\tilde{\theta}_{irsh}^F\right)^{\frac{\psi^{X,F}}{1+\psi^{X,F}\sigma}} \left(\frac{X_{rs}^F}{[P_{rs}^F]^{1-\sigma}}\right)^{\frac{\psi^{X,F}}{1+\psi^{X,F}\sigma}},$$

$$X_{irsh}^F = \left[\theta_{irh}^{X,F}(1+\tilde{t}_{ih}^{\text{av}})\right]^{\frac{1-\sigma}{1+\psi^{X,F}\sigma}} \left(\tilde{\theta}_{irsh}^F\right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}} \left(\frac{X_{rs}^F}{[P_{rs}^F]^{1-\sigma}}\right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}}.$$

Let us write

$$X_{irsh}^F = \varphi_{irsh} \left(\frac{X_{rs}^F}{[P_{rs}^F]^{1-\sigma}}\right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}}, \tag{E.10}$$

$$\text{where} \quad \varphi_{irsh} \equiv \left[\theta_{irh}^{X,F}(1+\tilde{t}_{ih}^{\text{av}})\right]^{\frac{1-\sigma}{1+\psi^{X,F}\sigma}} \left(\tilde{\theta}_{irsh}^F\right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}}. \tag{E.11}$$

Since $(P_{rs}^F)^{1-\sigma} = \sum_{h\in\mathcal{H}_s}\sum_{i\in\mathcal{R}_F} \tilde{\theta}_{irsh}^F [p_{irh}]^{1-\sigma}$,

$$P_{rs}^F = \left(X_{rs}^F\right)^{\frac{\psi^{X,F}}{1+\psi^{X,F}}} \left[\sum_{h\in\mathcal{H}_s}\sum_{i\in\mathcal{R}_F} \varphi_{irsh}\right]^{\frac{1+\psi^{X,F}\sigma}{(1+\psi^{X,F})(1-\sigma)}}. \tag{E.12}$$

Thus,

$$X_{irsh}^F = \frac{\varphi_{irsh}}{\sum_{v\in\mathcal{H}_s}\sum_{o\in\mathcal{R}_F} \varphi_{orsv}} X_{rs}^F. \tag{E.13}$$

Finally, $X_{rs}^F = \frac{\theta_{rs}^F [P_{rs}^F]^{1-\sigma}}{[P_{rs}]^{1-\sigma}} X_{rs}$ implies that

$$X_{rs}^F = \left(\theta_{rs}^F\right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}} \mu_{rs} \left(\frac{X_{rs}}{[P_{rs}]^{1-\sigma}}\right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}}, \tag{E.14}$$

$$\text{where} \quad \mu_{rs} \equiv \sum_{h \in \mathcal{H}_s} \sum_{i \in \mathcal{R}_F} \varphi_{irsh}. \tag{E.15}$$

Thus, substituting (E.14) into (E.12), we obtain

$$P_{rs}^F = \zeta_{rs} \left(\frac{X_{rs}}{[P_{rs}]^{1-\sigma}} \right)^{\frac{\psi^{X,F}}{1+\psi^{X,F}\sigma}}, \tag{E.16}$$

$$\text{where} \quad \zeta_{rs} \equiv \left(\theta_{rs}^F\right)^{\frac{\psi^{X,F}}{1+\psi^{X,F}\sigma}} [\mu_{rs}]^{\frac{1}{1-\sigma}}. \tag{E.17}$$

Combining (E.13) and (E.14) we can also write

$$X_{irsh}^F = \varphi_{irsh} \left(\theta_{rs}^F\right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}} \left(\frac{X_{rs}}{[P_{rs}]^{1-\sigma}} \right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}}, \tag{E.18}$$

and, using $T_{rs} \equiv \sum_{h \in \mathcal{H}_s} \sum_{i \in \mathcal{R}_F} \frac{\tilde{t}_{ih}^{\text{av}}}{1+\tilde{t}_{ih}^{\text{av}}} X_{irsh}^F$,

$$T_{rs} = \left(\frac{X_{rs}}{[P_{rs}]^{1-\sigma}} \right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}} \varphi_{rs}^R, \tag{E.19}$$

with

$$\varphi_{rs}^R \equiv \left(\theta_{rs}^F\right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}} \sum_{h \in \mathcal{H}_s} \sum_{i \in \mathcal{R}_F} \frac{\tilde{t}_{ih}^{\text{av}}}{1+\tilde{t}_{ih}^{\text{av}}} \varphi_{irsh}. \tag{E.20}$$

Combining (C.13) and (E.19), we can solve for domestic expenditure $\{X_{rs}\}$ as the solution to:

$$X_{rs} - \sum_{d \in \mathcal{R}_H} \sum_{k \in \mathcal{S}} \hat{e}_{rs,dk} (X_{dk})^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\kappa}} = \hat{X}_{rs}, \tag{E.21}$$

with

$$\hat{X}_{rs} = \xi_{rs} + \sum_{k \in \mathcal{S}} (\gamma_s \alpha_k + \alpha_{sk}) Y_{rk},$$

$$\hat{e}_{rs,dk} = \gamma_s \frac{N_r}{N} \varphi_{dk}^R \left([P_{dk}]^{\sigma-1}\right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}}, \tag{E.22}$$

where both $\{Y_{rk}\}$ and $\{P_{dk}\}$ are only functions of $\{p_{rs}\}$ and $\{P_{rs}^F\}$ via (C.9) and (E.4)–(E.6).

E.3. *Algorithm*

We use the following algorithm to solve for the competitive equilibrium of the model.

1. Compute parameters that are invariant to prices: φ_{rs}^R from (E.20), ζ_{rs} from (E.17), μ_{rs} from (E.15), φ_{irsh} from (E.11), and δ_{rs} from (C.15).

2. We have an outer loop (indexed by a). Guess $P_{rs}^{F,a=0}$ using (E.16):

$$P_{rs}^{F,a=0} = \zeta_{rs} \left(\tilde{E}_{rs}^{0} \right)^{\frac{\psi^{X,F}}{1+\psi^{X,F}\sigma}}, \tag{E.23}$$

where we use a pre-determined choice of the sector-level demand shifter $\tilde{E}_{rs}^{0} \equiv X_{rs}^{0}(P_{rs}^{0})^{\sigma-1}$ (which we take to be the value in some observed initial equilibrium).
3. Given $P_{rs}^{F,a}$, we have a middle loop (indexed by b) that solves for p_{rs}^{a}.
   (a) We guess $p_{rs}^{a,b=0} = \theta_{rds}$ for arbitrary d.
   (b) Given $\{P_{rs}^{F,a}, p_{rs}^{a,b}\}$, compute the following vectors of region-sector variables (with length $|\mathcal{R}_H| \cdot |\mathcal{S}|$ and same ordering of sectors and regions for all variables).
      i. Domestic region-sector price index $P_{rs}^{H,a,b}$ by substituting $p_{rs}^{a,b}$ into (E.5).
      ii. Region-sector price index $P_{rs}^{a,b}$ by substituting $P_{rs}^{F,a}$ and $P_{rs}^{H,a,b}$ into (E.4).
      iii. Region-sector supply $Y_{rs}^{a,b}$ by substituting $p_{rs}^{a,b}$ and $P_{rk}^{a,b}$ into (C.9).
      iv. Region-sector foreign demand $D_{rs}^{F,a,b}$ by substituting $p_{rs}^{a,b}$ into (C.15).
      v. Region-sector spending $X_{rs}^{a,b}$ using (E.21). Here, we have an inner fixed-problem algorithm (indexed by c):
         A. Compute $\hat{X}^{a,b} = [\hat{X}_{rs}]_{|\mathcal{R}_F|\cdot|\mathcal{S}|\times 1}$ and $\hat{e}^{a,b} \equiv [\hat{e}_{rs,dk}^{a,b}]_{|\mathcal{R}_F|\cdot|\mathcal{S}|\times|\mathcal{R}_F|\cdot|\mathcal{S}|}$ by plugging $Y_{rk}^{a,b}$ and $P_{dk}^{a,b}$ into (E.22).
         B. Guess that $X^{a,b,c=0} = \sum_{d=0}^{\bar{d}} (\hat{e}^{a,b})^{d} \hat{X}^{a,b}$.[13] Given $X^{a,b,c}$, compute

$$\widetilde{X}_{rs}^{a,b,c} \equiv \sum_{d\in\mathcal{R}_H} \sum_{k\in\mathcal{S}} \hat{e}_{rs,dk}^{a,b} \left(X_{d,k}^{a,b,c} \right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}} + \hat{X}_{r,s}^{a,b},$$

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

         If $max_{r,s}|Xerr_{rs}| < tol$, then we set $X^{a,b} = X^{a,b,c}$. Otherwise, we repeat the step with

$$X_{rs}^{a,b,c+1} = X_{rs}^{a,b,c} - \chi^{X} \left(X_{rs}^{a,b,c} - \widetilde{X}_{rs}^{a,b,c} \right).$$

         for $\chi^{X} > 0$ small enough. Note that, given our initial guess of $X^{a,b,c=0}$, this converges in a single step if $\psi^{X,F} = 0$.
      vi. Region-sector domestic spending $X_{rs}^{H,a,b}$ by substituting $P_{rs}^{H,a,b}$, $P_{rs}^{a,b}$ and $X_{rs}^{a,b}$ into (E.8).
      vii. Region-sector domestic demand $D_{rs}^{H,a,b}$ by substituting $p_{rs}^{a,b}$, $X_{rs}^{H,a,b}$ and $P_{rs}^{H,a,b}$ into (E.8) and (C.14).
      viii. Region-sector excess supply:

$$Yerr_{rs}^{a,b} \equiv \frac{Y_{rs}^{a,b} - (D_{r,s}^{F,a,b} + D_{rs}^{H,a,b})}{Y_{rs}^{a,b}}.$$

   (c) If $\max_{r,s}\{|Yerr_{rs}^{a,b}|\} < tol$, then proceed to step (iv) by setting $p_{rs}^{a} = p_{rs}^{a,b}$. If not, repeat (iii.b) with the updated guesses for prices:

$$\ln p_{rs}^{a,b+1} = \ln p_{rs}^{a,b} - \chi^{H} Yerr_{rs}^{a,b}$$

[13] $\bar{d}$ is a numerical parameter that can in principle be set to infinity. In practice, we set $\bar{d} = 5$.

for $\chi^H > 0$ small enough. Intuitively, supply is larger than demand when $Yerr_{rs}^{a,b} > 0$, so we reduce domestic prices in region r sector s until convergence.

4. Given the demand shifter $E_{rs}^a = X_{rs}^a (P_{rs}^a)^{\sigma-1}$, we compute the error in the import price index of each region-sector,

$$Perr_{rs} \equiv |P_{rs}^{F,a} - \zeta_{rs} \left(E_{rs}^a\right)^{\frac{\psi^{X,F}}{1+\psi^{X,F}\sigma}} |.$$

If $\max_{r,s}\{|Perr_{rs}|\} < tol$, then stop. If not, repeat step (iii) with the updated guess for prices:

$$P_{rs}^{F,a+1} = \zeta_{rs} \left(\tilde{E}_{rs}^{a+1}\right)^{\frac{\psi^{X,F}}{1+\psi^{X,F}\sigma}},$$

with

$$\tilde{E}_{rs}^{a+1} = \tilde{E}_{rs}^a - \chi^F (\tilde{E}_{rs}^a - E_{rs}^a)$$

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

5. Upon convergence, we compute X_{irsh}^F using (E.10) and (E.14), import prices p_{irh} using (E.9), import quantity $m_{irh} = X_{irsh}^F / p_{irh}$, region-sector value-added W_{rs} and wages $w_{rs} = \frac{W_{rs}}{L_{rs}}$ (with $L_{rs} = \phi_{rs} N_{rs}$) using (C.8), region-level consumption price index P_r^C using (C.12), and per-capita lump-sum transfers $\tau = \frac{1}{N}\sum_{r\in\mathcal{R}_H, s\in\mathcal{S}} T_{rs}$ with T_{rs} given by (E.19).

APPENDIX F: ANALYTICAL JACOBIAN MATRICES

F.1. *Jacobians with Respect to Imports*

In this section, we derive analytical expressions for the derivatives of imports, wages, consumption price indices, country-specific terms-of-trade, and fiscal externalities with respect to imports of each country-product variety. Our derivation is based on the linearization of three key blocks of the model: an import pricing block, a domestic output market clearing block, and a domestic expenditures block. Linearizing these three blocks allows us to compute the Jacobians of P^F_{rs}, p_{rs}, and X_{rs} with respect to tariffs $1+t^{\text{av}}_{ih}$. More straightforward linearizations then connect changes in these variables to changes in our variables of interest as well as—critically—changes in imports. We then invert the relationship between imports and tariffs to solve for the Jacobians of our variables of interest with respect to imports.

F.1.1. *Jacobians with Respect to Tariffs*

We now derive the Jacobians of P^F_{rs}, p_{rs}, and X_{rs} with respect to tariffs $1+t^{\text{av}}_{ih}$. We do so by first linearizing three key blocks of the model and then combining these blocks.

F.1.1.1. *Import Pricing Block.* The first equation relates changes in spending, changes region-sector prices, changes in Foreign price indices, and changes in tariffs using equations (E.16), (E.17), (E.15), (E.11), (E.4) and (E.5). We have

$$P^F_{rs} = \zeta_{rs}\left(\frac{X_{rs}}{[P_{rs}]^{1-\sigma}}\right)^{\frac{\psi^{X,F}}{1+\psi^{X,F}\sigma}}$$

$$\text{where}\quad \zeta_{rs} \equiv \left(\theta^F_{rs}\right)^{\frac{\psi^{X,F}}{1+\psi^{X,F}\sigma}}\left(\mu_{rs}\right)^{\frac{1}{1-\sigma}}$$

$$\mu_{rs} \equiv \sum_{h\in\mathcal{H}_s}\sum_{i\in\mathcal{R}_F}\varphi_{irsh}$$

$$\varphi_{irsh} \equiv \left[\theta^{X,F}_{irh}(1+\tilde{t}^{\text{av}}_{ih})\right]^{\frac{1-\sigma}{1+\psi^{X,F}\sigma}}\left(\tilde{\theta}^F_{irsh}\right)^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}}$$

$$P_{rk} = \left[\sum_{c=H,F}\theta^c_{rk}[P^c_{rk}]^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$$

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

To linearize this system of equations, first define the $|\mathcal{R}_F||\mathcal{S}|$-dimensional matrices and vectors

$$[\boldsymbol{\Omega^H}]_{rs,ok} \equiv \frac{X^H_{ors}}{X^H_{rs}}\mathbb{1}_{k=s} \qquad [\boldsymbol{s^F}]_{rs} \equiv \frac{X^F_{rs}}{X_{rs}}$$

$$[\boldsymbol{\Omega^F}]_{rs,ih} \equiv \frac{X^F_{irsh}}{X^F_{rs}} \qquad [\tilde{\boldsymbol{t}}]_{ih} \equiv \tilde{t}^{\text{av}}_{ih}$$

where $\mathrm{Diag}(\boldsymbol{x})$ denotes the diagonal matrix whose entries are given by the vector $\boldsymbol{x}$. Log-linearizing these equations implies the following matrix equation:

$$\boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{P^F}} d\log \boldsymbol{P}^F = \boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{X}} d\log \boldsymbol{X} + \boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{p}} d\log \boldsymbol{p} + \boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{1+t^{av}}} d\log(\boldsymbol{1}+\tilde{\boldsymbol{t}}) \tag{F.1}$$

$$\begin{aligned} \text{where}\quad \boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{P^F}} &\equiv \big((1+\psi^{X,F}\sigma)\boldsymbol{I} + \psi^{X,F}(1-\sigma)\mathrm{Diag}(\boldsymbol{s^F})\big) \\ \boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{X}} &\equiv \psi^{X,F}\boldsymbol{I} \\ \boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{p}} &\equiv \psi^{X,F}(\sigma-1)(\boldsymbol{I}-\mathrm{Diag}(\boldsymbol{s^F}))\boldsymbol{\Omega^H} \\ \boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{1+t^{av}}} &\equiv \boldsymbol{\Omega^F} \end{aligned}$$

F.1.1.2. *Domestic Output Block.* The second equation relates changes in spending, changes region-sector prices, and changes in Foreign price indices using Equations (C.16), (C.9) (C.15), (C.14), (E.8), (E.4) and (E.5). We have

$$\begin{aligned} Y_{rs} &= D^F_{rs} + D^H_{rs} \\ \text{where}\quad Y_{rs} &= L_{rs}(p_{rs})^{1/\alpha_s}\prod_{k\in\mathcal{S}}[\alpha_{ks}/P_{rk}]^{\alpha_{ks}/\alpha_s} \\ D^F_{rs} &= \delta_{rs}(p_{rs})^{1-1/\psi^{M,F}} \\ D^H_{rs} &= \sum_{d\in\mathcal{R}_H} X^H_{rds} \\ \delta_{rs} &= \sum_{i\in\mathcal{R}_F}(\theta_{ris})^{-(1-1/\psi^{M,F})}\sum_{h\in\mathcal{H}_s}\left(\theta^{M,F}_{rih}\right)^{1/\psi^{M,F}} \end{aligned}$$

$$\begin{aligned} X^H_{ors} &= \frac{\tilde{\theta}^H_{ors}[p_{os}]^{1-\sigma}}{[P^H_{rs}]^{1-\sigma}}X^H_{rs} \\ X^H_{rs} &= \frac{\theta^H_{rs}[P^H_{rs}]^{1-\sigma}}{[P_{rs}]^{1-\sigma}}X_{rs} \\ P_{rk} &= \left[\sum_{c=H,F}\theta^c_{rk}[P^c_{rk}]^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \\ P^H_{rk} &= \left[\sum_{o\in\mathcal{R}_H}\tilde{\theta}^H_{ork}[p_{ok}]^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \end{aligned}$$

Define the $|\mathcal{R}_F||\mathcal{S}|$-dimensional matrices and vectors

$$[\boldsymbol{A}]_{rs,dk} \equiv \frac{\alpha_{ks}}{\alpha_s}\mathbb{1}_{d=r} \qquad [\boldsymbol{\alpha^w}]_{rs} \equiv \alpha_s$$

$$[\boldsymbol{\Omega^D}]_{rs,dk} \equiv \frac{X^H_{rds}}{Y_{rs}}\mathbb{1}_{s=k} \qquad [\boldsymbol{\sigma^p}]_{rs} \equiv \frac{D^F_{rs}}{Y_{rs}}(1-1/\psi^{M,F}) + \frac{D^H_{rs}}{Y_{rs}}(1-\sigma)$$

$$[\boldsymbol{\sigma^H}]_{rs} \equiv -(1-\sigma)(1-\boldsymbol{s}^{\boldsymbol{F}}_{rs})$$

Log-linearizing these equations implies the following matrix equation:

$$\begin{aligned}
\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{p}} d\log \boldsymbol{p} =& \boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{X}} d\log \boldsymbol{X} + \boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{P^F}} d\log \boldsymbol{P^F} \qquad \text{(F.2)}\\
\text{where} \quad \boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{p}} \equiv& \left(\text{Diag}(\boldsymbol{\alpha^w})^{-1} - \text{Diag}(\boldsymbol{\sigma^p})\right) - \left(\boldsymbol{A}\cdot\text{Diag}(1-\boldsymbol{s^F}) + \boldsymbol{\Omega^D}\text{Diag}(\boldsymbol{\sigma^H})\right)\boldsymbol{\Omega^H}\\
\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{X}} \equiv& \boldsymbol{\Omega^D}\\
\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{P^F}} \equiv& ((\sigma-1)\boldsymbol{\Omega^D} + \boldsymbol{A})\text{Diag}(\boldsymbol{s^F})
\end{aligned}$$

Domestic Expenditures Block The third equation relates changes in spending, changes region-sector prices, changes in Foreign price indices, and changes in tariffs using Equations (C.13), (C.9) (E.1), (E.18), (E.4), (E.5), (E.11), and (E.15). We have

$$\begin{aligned}
X_{rs} &= \xi_{rs} + \gamma_{rs} N_r \tau + \sum_{k\in\mathcal{S}} (\gamma_{rs}\alpha_k + \alpha_{sk}) Y_{rk}\\
\text{where} \quad Y_{rs} &= L_{rs}(p_{rs})^{1/\alpha_s} \prod_{k\in\mathcal{S}} [\alpha_{ks}/P_{rk}]^{\alpha_{ks}/\alpha_s}\\
\tau &= \frac{1}{N} \sum_{i\in\mathcal{R}_F}\sum_{r\in\mathcal{R}_H}\sum_{s\in\mathcal{S}}\sum_{h\in\mathcal{H}_s} \frac{t^{\text{av}}_{ih}}{1+t^{\text{av}}_{ih}} X^F_{irsh}\\
X^F_{irsh} &= \frac{\varphi_{irsh}}{\sum\limits_{o\in\mathcal{R}_F, v\in\mathcal{H}_s} \varphi_{orsv}} \frac{\theta^F_{rs}[P^F_{rs}]^{1-\sigma}}{[P_{rs}]^{1-\sigma}} X_{rs},\\
P_{rk} &= \left[\sum_{c=H,F} \theta^c_{rk}[P^c_{rk}]^{1-\sigma}\right]^{\frac{1}{1-\sigma}}\\
P^H_{rk} &= \left[\sum_{o\in\mathcal{R}_H} \tilde{\theta}^H_{ork}[p_{ok}]^{1-\sigma}\right]^{\frac{1}{1-\sigma}}\\
\varphi_{irsh} &= [\theta^{X,F}_{irh}(1+t^{\text{av}}_{ih})]^{\frac{1-\sigma}{1+\psi^{X,F}\sigma}} (\theta^F_{irsh})^{\frac{1+\psi^{X,F}}{1+\psi^{X,F}\sigma}}\\
\mu_{rs} &= \sum_{h\in\mathcal{H}_s}\sum_{i\in\mathcal{R}_F} \varphi_{irsh}
\end{aligned}$$

Define the $|\mathcal{R}_F||\mathcal{S}|$-dimensional matrices and vectors

$$\begin{aligned}
[\boldsymbol{A^I}]_{rs,dk} &\equiv \frac{Y_{rk}}{X_{rs}}(\gamma_{rs}\alpha_k + \alpha_{sk})\mathbb{1}_{d=r}\\
[\boldsymbol{s^\tau}]_{rs} &\equiv \frac{\gamma_{rs}N_r}{X_{r,s}N}\\
[\boldsymbol{T^s}]_{rs} &\equiv \sum_{i\in\mathcal{R}_F}\sum_{h\in\mathcal{H}_s} T_{irsh}
\end{aligned}$$

$$[\boldsymbol{\omega}^{\boldsymbol{T}}]_{oh} \equiv \sum_d \frac{X^F_{ods(h)h}}{1+t^{\text{av}}_{oh}} + \frac{1-\sigma}{1+\psi^{X,F}\sigma} \sum_{d \in \mathcal{R}_H} \left(T_{ods(h)h} - T_{rs(h)} \frac{X^F_{ods(h)v}}{X^F_{ds(h)}} \right)$$

Log-linearizing these equations implies the following matrix equation:

$$\boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{X}} d\log \boldsymbol{X} = \boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{p}} d\log \boldsymbol{p} + \boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{P^F}} d\log \boldsymbol{P^F} + \boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{1+t^{av}}} d\log(\boldsymbol{1}+\tilde{\boldsymbol{t}}) \tag{F.3}$$

$$\text{where} \quad \boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{X}} \equiv \boldsymbol{I} - \boldsymbol{s^\tau} \boldsymbol{T}^{s\prime}$$

$$\boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{p}} \equiv \boldsymbol{A^I}\text{Diag}(\boldsymbol{\alpha^w})^{-1} - \left(\boldsymbol{A^I A} + (1-\sigma)\boldsymbol{s^\tau T}^{s\prime}\right)(\boldsymbol{I} - \text{Diag}(\boldsymbol{s^F}))\boldsymbol{\Omega^H}$$

$$\boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{P^F}} \equiv (1-\sigma)s^\tau \boldsymbol{T}^s - \left(\boldsymbol{A^I A} + (1-\sigma)\boldsymbol{s^\tau T}^{s\prime}\right)\text{Diag}(\boldsymbol{s^F})$$

$$\boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{1+t^{av}}} \equiv \boldsymbol{s^\tau} \boldsymbol{\omega}^{T\prime}$$

F.1.1.3. *Jacobians with Respect to Tariff Changes* Substituting equations (F.1)-(F.3) into one another implies

$$d\log \boldsymbol{X} = \boldsymbol{A^X} d\log(\boldsymbol{1}+\tilde{\boldsymbol{t}}) \tag{F.4}$$

$$d\log \boldsymbol{P^F} = \boldsymbol{A^{P^F}} d\log(\boldsymbol{1}+\tilde{\boldsymbol{t}}) \tag{F.5}$$

$$d\log \boldsymbol{p} = \boldsymbol{A^p} d\log(\boldsymbol{1}+\tilde{\boldsymbol{t}}) \tag{F.6}$$

where

$$\boldsymbol{A^X} \equiv \left(\boldsymbol{Q^X_X} - \boldsymbol{Q^X_{P^F}}(\boldsymbol{Q^{P^F}_{P^F}})^{-1}\boldsymbol{Q^{P^F}_X}\right)^{-1}(\boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{1+t^{av}}} + \boldsymbol{Q^X_{P^F}}(\boldsymbol{Q^{P^F}_{P^F}})^{-1}\boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{1+t^{av}}})$$

$$\boldsymbol{A^{P^F}} \equiv \left(\boldsymbol{Q^{P^F}_{P^F}} - \boldsymbol{Q^{P^F}_X}(\boldsymbol{Q^X_X})^{-1}\boldsymbol{Q^X_{P^F}}\right)^{-1}(\boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{1+t^{av}}} + \boldsymbol{Q^{P^F}_X}(\boldsymbol{Q^X_X})^{-1}\boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{1+t^{av}}})$$

$$\boldsymbol{A^p} \equiv (\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{p}})^{-1}\left(\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{X}}\boldsymbol{A^X} + \boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{P^F}}\boldsymbol{A^{P^F}}\right)$$

$$\boldsymbol{Q^{P^F}_{P^F}} \equiv \boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{P^F}} - \boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{p}}(\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{p}})^{-1}\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{P^F}}$$

$$\boldsymbol{Q^{P^F}_X} \equiv \boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{X}} + \boldsymbol{\mathcal{E}}^{\boldsymbol{P^F}}_{\boldsymbol{p}}(\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{p}})^{-1}\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{X}}$$

$$\boldsymbol{Q^X_X} \equiv \boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{X}} - \boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{p}}(\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{p}})^{-1}\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{X}}$$

$$\boldsymbol{Q^X_{P^F}} \equiv \boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{P^F}} + \boldsymbol{\mathcal{E}}^{\boldsymbol{X}}_{\boldsymbol{p}}(\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{p}})^{-1}\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{P^F}}$$

F.1.1.4. *Domestic Prices, Consumer Prices, Wages, Imports, and Terms of Trade.* We now use the Jacobian matrices described in equations (F.4)-(F.6) to compute the Jacobian matrices of domestic price indices, consumer price indices, wages, imports and terms of trade with respect to tariffs.[14]

[14]We follow analogous steps to compute fiscal externalities through tariffs omitted from estimation, production subsidies, and income taxes. We omit these derivations for brevity.

1. Domestic prices: From equations (E.4) and (E.5), we have

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

   Log-linearizing and substituting equations (F.5) and (F.6) implies

$$d\log \boldsymbol{P} = \boldsymbol{A^P} d\log(\boldsymbol{1} + \tilde{\boldsymbol{t}}) \tag{F.7}$$
$$\text{where} \quad \boldsymbol{A^P} \equiv \left[\boldsymbol{I} - \text{Diag}(\boldsymbol{s^F})\right] \boldsymbol{\Omega^H} \boldsymbol{A^p} + \text{Diag}(\boldsymbol{s^F}) \boldsymbol{A^{P^F}}$$

2. Consumer prices: From equation (C.12), we have

$$P^C_r = \prod_{k \in \mathcal{S}} (P_{rk})^{\gamma_k}.$$

   Log-linearizing and substituting equation (F.7) implies

$$d\log \boldsymbol{P^C} = \boldsymbol{A^{P^C}} d\log(\boldsymbol{1} + \tilde{\boldsymbol{t}})$$
$$\text{where} \quad [\boldsymbol{A^{P^C}}]_{r,ih} \equiv \sum_{s \in \mathcal{S}} \gamma_s [\boldsymbol{A^P}]_{rs,ih}$$

3. Wages: Since labor is the only factor and labor endowments are fixed, the change in wages w_{rs} is the same as the change in value added Y_{rs}. We have from equation (C.9) that

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

   Log-linearizing and substituting equations (F.6) and (F.7) implies

$$d\log \boldsymbol{w} = \boldsymbol{A^w} d\log(\boldsymbol{1} + \tilde{\boldsymbol{t}})$$
$$\text{where} \quad \boldsymbol{A^w} \equiv \text{Diag}(\boldsymbol{\alpha}^w)^{-1} \boldsymbol{A^p} - \boldsymbol{A} \boldsymbol{A^P}$$

4. Imports: From equations (15), (E.9), (E.18), (E.7), (E.4), and (E.5) we know

$$p^{X,F}_{irh} = \theta^{X,F}_{irh} (q^{X,F}_{irh})^{\psi^{X,F}}$$
$$p_{irh} = \left[\theta^{X,F}_{irh} (1 + \tilde{t}^{\text{av}}_{ih})\right]^{\frac{1}{1+\psi^{X,F}}} (X^F_{irsh})^{\frac{\psi^{X,F}}{1+\psi^{X,F}}}$$
$$X^F_{irsh} = \frac{\varphi_{irsh}}{\mu_{rs}} X^F_{rs}$$
$$X^F_{rs} = \frac{\theta^F_{rs} [P^F_{rs}]^{1-\sigma}}{[P_{rs}]^{1-\sigma}} X_{rs}$$
$$P_{rk} = \left[\theta^F_{rk} [P^F_{rk}]^{1-\sigma} + \sum_{o \in \mathcal{R}_H} \theta^H_{rk} \tilde{\theta}^H_{ork} [p_{ok}]^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

We denote total imports of h from i by

$$m_{ih} \equiv \sum_{r \in \mathcal{R}_H} q^{X,F}_{irh}.$$

Log-linearizing, using the fact that $p_{irh} = p^{X,F}_{irh}(1 + t^{av}_{ih})$, and using equations F.4, F.5, and F.7 implies

$$\begin{aligned}
d\ln \boldsymbol{m} &= \boldsymbol{A^m} d\ln(\boldsymbol{1} + \tilde{\boldsymbol{t}}) \\
\text{where} \quad \boldsymbol{A^m} &\equiv \frac{1}{1+\psi^{X,F}} \left[\boldsymbol{\Psi} + \boldsymbol{\Omega^X} \left(\boldsymbol{A^X} + (1-\sigma) \left(\boldsymbol{A^{P^F}} - \boldsymbol{A^P} \right) \right) \right] \\
[\boldsymbol{\Psi}]_{ih,ov} &= -\mathbb{1}_{i=o,h=v} \frac{(1+\psi^{X,F})\sigma}{1+\psi^{X,F}\sigma} - \frac{1-\sigma}{1+\psi^{X,F}\sigma} \mathbb{1}_{s(h)=s(v)} \sum_{r \in \mathcal{R}_H} \frac{q^{X,F}_{irh}}{m_{ih}} \frac{X^F_{ors(v)v}}{X^F_{rs(v)}} \\
[\boldsymbol{\Omega^X}]_{ih,rs} &= \mathbb{1}_{h \in \mathcal{H}_s} \frac{q^{X,F}_{irh}}{m_{ih}}
\end{aligned}$$

5. Terms of trade: The terms-of-trade effects that Home experiences from a change in export and import prices, respectively, vis-a-vis country-sector (i, s) are given by

$$\begin{aligned}
d\mathrm{TOT}^{X,F}_{is} &= \sum_{r,h \in \mathcal{H}_s} q^{X,F}_{irh} \, \mathrm{d}p^{X,F}_{irh} \\
d\mathrm{TOT}^{M,F}_{is} &= - \sum_{r,h \in \mathcal{H}_s} q^{M,F}_{irh} \, \mathrm{d}p^{M,F}_{irh}
\end{aligned}$$

Note that we normalize terms-of-trade effects such that a positive terms-of-trade effect corresponds to an aggregate welfare decrease in Home. From equations (15), (16), (E.18), (E.7), and (C.1) (and the absence of export taxes) we know

$$\begin{aligned}
p^{X,F}_{irh} &= \theta^{X,F}_{irh} (q^{X,F}_{irh})^{\psi^{X,F}} \\
p^{M,F}_{rih} &= \theta^{M,F}_{rih} (q^{M,F}_{rih})^{-\psi^{M,F}} \\
X^F_{irsh} &= \frac{\varphi_{irsh}}{\mu_{rs}} X^F_{rs} \\
X^F_{rs} &= \frac{\theta^F_{rs} [P^F_{rs}]^{1-\sigma}}{[P_{rs}]^{1-\sigma}} X_{rs} \\
p^{X,F}_{irh} &= (\theta_{irh})^{-1} p_{rs(h)},
\end{aligned}$$

Log-linearizing and using equations F.4, F.5, F.7, and F.6 implies

$$\begin{aligned}
d\boldsymbol{ToT^{X,F}} &= \boldsymbol{A^{TOT^{X,F}}} d\ln(\boldsymbol{1} + \tilde{\boldsymbol{t}}) \\
\text{where} \quad \boldsymbol{A^{TOT^{X,F}}} &\equiv \frac{\psi^{X,F}}{\psi^{X,F}+1} \left[\boldsymbol{\Gamma} - \tilde{\mathbf{X}} \left(\boldsymbol{A^X} + (1-\sigma)(\boldsymbol{A^{P^F}} - \boldsymbol{A^P}) \right) \right] \\
[\boldsymbol{\Gamma}]_{is,oh} &\equiv \mathbb{1}_{i=o,s(h)=s} \frac{(1+\psi^{X,F})\sigma}{1+\psi^{X,F}\sigma} \sum_{r \in \mathcal{R}_H} \frac{X^F_{irsh}}{1+t^{av}_{ih}}
\end{aligned}$$

$$+\mathbb{1}_{s(h)=s}\frac{1-\sigma}{1+\psi^{X,F}\sigma}\sum_{r\in\mathcal{H}_s}\left(\sum_{v\in\mathcal{H}_s}\frac{X^F_{irsv}}{1+t^{av}_{iv}}\right)\frac{X^F_{orsh}}{X^F_{rs}}$$

$$[\tilde{\mathbf{X}}]_{is,rk}\equiv-\mathbb{1}_{s=k}\sum_{r,h\in\mathcal{H}_s}\frac{X^F_{irsh}}{1+t^{av}_{ih}}$$

and

$$d\boldsymbol{ToT^{M,F}}=\boldsymbol{A^{ToT^{M,F}}}\,d\ln\boldsymbol{p}$$

$$\text{where}\quad[\boldsymbol{A^{ToT^{M,F}}}]_{is,rk}\equiv\mathbb{1}_{s=k}\sum_{h\in\mathcal{H}_s}p^{M,F}_{irh}q^{M,F}_{irh}$$

F.1.1.5. *From Tariff to Import Changes.* The last step of our derivation is to convert the Jacobian matrices above—which are derivatives with respect to tariff changes—into the Jacobian matrices that enter our estimating equation—which are derivatives with respect to import changes. We do so by multiplying each original Jacobian matrix by the inverse of the Jacobian matrix of imports with respect to tariffs:

$$\frac{d\log\boldsymbol{P^C}}{d\log\boldsymbol{m}}=\boldsymbol{A^{P^C}}[\boldsymbol{A^m}]^{-1},$$

$$\frac{d\log\boldsymbol{w}}{d\log\boldsymbol{m}}=\boldsymbol{A^w}[\boldsymbol{A^m}]^{-1},$$

$$\frac{d\boldsymbol{ToT^{X,F}}}{d\log\boldsymbol{m}}=\boldsymbol{A^w}[\boldsymbol{A^m}]^{-1},$$

$$\frac{d\boldsymbol{ToT^{M,F}}}{d\log\boldsymbol{m}}=\boldsymbol{A^w}[\boldsymbol{A^m}]^{-1}.$$

F.2. *Jacobian Matrices with Respect to Foreign Tariffs*

We now turn to the analytical expression for the derivative of wages with respect to foreign tariffs, which we use for the model-testing exercise in Section 3.5. Note that although we have not introduced foreign tariffs explicitly in our model, equation (16) implies that the impact of $d\log(1+t^{F,\text{av}}_{ih})$, is equivalent to that of $d\log\theta^{M,F}_{rih}=-d\log(1+t^{F,\text{av}}_{ih})$ for all $r\in\mathcal{R}_H$. We can therefore characterize Jacobian matrices with respect to foreign tariffs by characterizing Jacobian matrices with respect to changes in foreign import demand shifters that are uniform across domestic regions, as we do below. In such cases we denote by $d\log\theta^{M,F}_{ih}$ the common value across all r of $d\log\theta^{M,F}_{rih}$.

F.2.0.1. *Revisiting the Domestic Output Block.* We now revisit the three key blocks of the model studied in Appendix (F.1). Of these, the import pricing and domestic expenditures blocks are as before, except for that we may now ignore changes in Home tariffs. However, the domestic output block changes since it depends on Home exports. Importantly, we now have

$$d\log\delta_{rs}=\frac{1}{\psi^{M,F}}\sum_{i\in\mathcal{R}_F}\sum_{h\in\mathcal{H}_s}\frac{\delta_{irsh}}{\delta_{rs}}d\log\theta^{M,F}_{ih}$$

$$\text{where}\quad\delta_{irsh}\equiv(\theta_{ris})^{-(1-1/\psi^{M,F})}\left(\theta^{M,F}_{rih}\right)^{1/\psi^{M,F}}$$

By equations (16) and (C.1) and the absence of export taxes,

$$\begin{aligned} p^{M,F}_{rih} q^{M,F}_{rih} &= (p^{M,F}_{ris})^{1-1/\psi^{M,F}} (\theta^{M,F}_{rih})^{1/\psi^{M,F}} = \delta_{irsh} p_{rs} \\ \implies \quad \delta_{irsh}/\delta_{rs} &= p^{M,F}_{rih} q^{M,F}_{rih} / D^F_{rs} \end{aligned}$$

Combining these steps with our earlier analysis implies

$$\begin{aligned} \boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{p}} d\log \boldsymbol{p} &= \boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{X}} d\log \boldsymbol{X} + \boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{P^F}} d\log \boldsymbol{P^F} + \boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{\theta^{M,F}}} d\log \boldsymbol{\theta^{M,F}} \qquad \text{(F.8)} \\ \text{where} \quad [\boldsymbol{\mathcal{E}}^{\boldsymbol{p}}_{\boldsymbol{\theta^{M,F}}}]_{rs,ih} &\equiv \frac{1}{\psi^{M,F}} \mathbb{1}_{s=s(h)} \frac{p^{M,F}_{rih} q^{M,F}_{rih}}{Y_{rs}} \end{aligned}$$

F.2.0.2. *Changes in Value Added with Respect to Foreign Demand.* We combine the three blocks of the model analogously to Appendix (F.1) in order to arrive at Jacobians $d\log \boldsymbol{p}/d\log \boldsymbol{\theta^{M,F}}$ and $d\log \boldsymbol{P^F}/d\log \boldsymbol{\theta^{M,F}}$ of Home output prices and import price indices with respect to foreign demand shocks. Finally, to compute the changes in region-sector value added (or equivalently wage bills) with respect to foreign demand shocks, we use that (a) the Cobb-Douglas nature of production implies log changes in wage bills equal log changes in output and (b) from equations (C.9), (E.4), and (E.5) we know

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

$$P_{rk} = \left[\theta^F_{rk}[P^F_{rk}]^{1-\sigma} + \sum_{o\in\mathcal{R}_H} \theta^H_{rk} \tilde{\theta}^H_{ork} [p_{ok}]^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

Log-linearizing implies

$$\begin{aligned} \frac{d\log \boldsymbol{w}}{d\log \boldsymbol{\theta^{M,F}}} &= \boldsymbol{\mathcal{E}}^{\boldsymbol{w}}_{\boldsymbol{p}} \frac{d\log \boldsymbol{p}}{d\log \boldsymbol{\theta^{M,F}}} + \boldsymbol{\mathcal{E}}^{\boldsymbol{w}}_{\boldsymbol{P^F}} \frac{d\log \boldsymbol{P^F}}{d\log \boldsymbol{\theta^{M,F}}}. \\ \text{where} \quad \boldsymbol{\mathcal{E}}^{\boldsymbol{W}}_{\boldsymbol{p}} &\equiv \text{Diag}\left(\boldsymbol{\alpha}^w\right)^{-1} - \boldsymbol{A}\left[\boldsymbol{I} - \text{Diag}\left(\boldsymbol{s^F}\right)\right] \boldsymbol{\Omega^H} \\ \boldsymbol{\mathcal{E}}^{\boldsymbol{w}}_{\boldsymbol{P^F}} &\equiv -\boldsymbol{A}\text{Diag}\left(\boldsymbol{s^F}\right) \end{aligned}$$

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