Interdependence of Trade Policies in General Equilibrium*

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Abstract

If governments are banned from using certain trade policy instruments, they may resort to other instruments to compensate for their lost policy space. The welfare effects of trade policy reforms, therefore, depend critically on the interdependence of various policy instruments at the governments' disposal. Using a multi-industry general-equilibrium Ricardian trade model we find that: (i) Restricting export subsidies/taxes leads to trade liberalization, but restricting import tariffs in isolation has no such effect; (ii) If export subsidies are already restricted, negotiated tariff cuts in a subset of industries lead to unilateral cuts in other industries; and (iii) A free trade agreement that precludes the use of trade taxes may lead to the adoption of wasteful trade barriers by welfare-maximizing governments. Fitting our model to trade data for 40 major countries, we show that these effects are quantitatively significant.

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1 Introduction

Policy interdependence concerns the effect of changes in a subset of policies on the tradeoffs that policymakers face elsewhere in the economy. For example, in response to constraints imposed on a subset of trade policies—due to trade agreements, political shocks, or domestic regulations—governments may find it optimal to adjust their unconstrained trade policies. These anticipated changes in unconstrained policies complicate the calculus of gains from trade liberalizations—which has been an important area of inquiry in the trade literature—and, more generally, any trade policy reforms.

Policy interdependence may be specially consequential in the case of *incomplete* or *gradual* trade agreements under which only a subset of industries and the policy instruments at the government's disposal are restricted. Under the WTO, for example, many countries have committed to substantial tariff cuts only in a subset of sectors, while retaining flexibility in setting their policy unilaterally in other sectors.[1] Another important example is given by the GATT/WTO's focus on a subset of policy instruments and sectors. Notably, the member countries adopted a strict ban on export subsidies early-on in their negotiations—well before binding constraints were negotiated for import tariffs on a majority of products.

The ultimate gains from negotiated trade liberalizations, therefore, cannot be fully understood unless one can predict the governments policy response in unrestricted and hidden policy instruments. For example, if tariffs across products are complementary, negotiated liberalization in a subset of products will lead to further unilateral liberalizations in unliberalized products. In contrast, if tariffs are substitute across products, the benefit of negotiated liberalization in a subset

[1] See Beshkar et al. (2015); Beshkar and Bond (2017) for an analysis of flexibility in trade agreements.

of products may be offset by an endogenous increase in tariffs on other products. The expected gains from negotiated trade liberalization may be also undermined if the governments turn to using hidden trade barriers, which may be even less efficient than tariffs.

Despite their critical role in analyzing cooperative and non-cooperative trade policies, the consequences of policy interdependence have largely escaped notice in the economic literature.[2] Our objective in this paper is to take a step toward closing this gap in the literature by characterizing the interdependence of various trade policy instruments in a multi-industry general-equilibrium model. We work within a Ricardian model of international trade with general consumer preferences and a full set of import and export tax instruments at the product level. This framework embeds important quantitative models of trade that have been used intensively in the trade literature, e.g., Eaton and Kortum (2002) and Costinot et al. (2012).

To characterize policy interdependence, we introduce various restrictions on the government's policy space and re-optimize the policy problem to find the government's optimal response in the free instruments. We introduce the restrictions on the policy space in a sequence that reflects the observed gradualism in the GATT/WTO pattern of liberalization over time. In particular, we first introduce a ban on export policy and determine the government's optimal response in the use of import policy. This scenario is meant to reflect the GATT/WTO's expansive ban on export subsidies and the domestic institutional constraints on export taxes in many countries. We then introduce a ban on import tariffs in a subset of sectors

[2] As we will discuss further below, there are notable exception including a literature on Free Trade Areas in which the interdependence of internal and external tariffs are studied; Horn et al. (2010), who study the effect of substitutability between import tariffs and production subsidy on the optimal design of incomplete contracts; and Beshkar and Shourideh (2020), who analyze the interdependence of trade and capital control taxes.

and find the optimal response of the government in unrestricted import sectors. Finally, we consider a scenario in which all observable import and export policies (i.e., taxes and subsidies) are negotiated away but the governments have the ability to erect hidden trade barriers.

Our results on the interdependence of trade policies are threefold. First, we find that import policy is an *imperfect* substitute for export policy. In particular, we find that the equilibrium obtained under optimal import tariffs can be exactly replicated with a set of export policies, but no set of import tariffs could replicate the equilibrium under optimal export taxes. An important implication of this result—presented in Corollary 1— is that the elimination of export subsidies would lead to an increase in trade volume.[3] This insight is in contrast to one obtained under a partial-equilibrium analysis in which the elimination of export subsidies will necessarily reduce trade volumes.

The above results provides a novel perspective on the GATT/WTO's ban on export subsidies. As reviewed by Lee (2016), the terms-of-trade literature has found it "quite difficult to justify the prohibition of export subsidies given the trade-volume-expanding nature of export subsidies." Our general-equilibrium analysis provides a potential explanation for this puzzle, because we show that the elimination of export subsidies will spur unilateral tariff cuts to a degree that leads to an overall increase in trade volumes.

Our second interdependence result is on the interdependence of industry-specific import tariffs.[4] We find that, under mild conditions, import tariffs across industries are complementary, namely, trade liberalization in a subset of sectors

[3]Within our model, this result is valid under a scenario in which the government could not use export taxes due to political or institutional constraints such as the constitutional ban on export taxes in the United States.

[4]See Proposition 3.

reduces the marginal gains from tariffs in other sectors, which induces the governments to cut their tariffs unilaterally in unconstrained industries. This finding is in line with Martin and Ng's (2004) observation that after entering the WTO, many developing countries started cutting their tariffs beyond their obligations under the agreement. Baldwin (2010) also highlights these unilateral tariff liberalizations, but provides an alternative explanation based on the fragmentation of the production processes.

The tariff complementarity result has interesting implications for the optimal breadth of trade agreements when negotiations are costly. In particular, if tariff cut negotiations are costly and these costs are increasing in the number of tariff lines included in negotiations, it may be optimal to restrict negotiations to a subset of industries. To see this, note that as more products are imported tax-free, the government would voluntarily reduce its tariffs on other products, which reduces the value of further negotiations. Therefore, if negotiation costs are sufficiently high, the governments would find it optimal to negotiate liberalization on only a subset of products.

Our final theoretical result concerns the use of Non-Revenue Trade Barriers (NRTBs), also known as wasteful trade barriers, as a substitute for import tariffs.[5] From the perspective of the standard terms-of-trade analysis, the adoption of NRTBs is hard to explain because such measures reduce trade without compensating the resulting consumption losses with a better terms of trade. Under a multi-industry general-equilibrium framework, however, we show that NRTBs could improve a country's welfare because restricting imports in one industry improves a country's terms of trade in *all other industries* by depressing foreign factor rewards. Therefore, if the consumption loss due to import restriction in an in-

[5] See Proposition 4.

dustry is sufficiently small, imposing an NRTB in that industry could be welfare-improving. We show that this condition is satisfied in relatively homogenous sectors where imported varieties could be easily substituted with domestic counterparts.

Our result concerning the optimality of NRTBs sheds fresh light on measures such as import bans and inefficient customs regulations (i.e., red tapes at the border) that discourage imports but do not generate revenues. These measure are quite prevalent in practice. For example, in the wake of negotiated tariff cuts, many countries have opted for non-tariff barriers that do not generate any revenues for the governments (Goldberg and Pavcnik 2016).

To obtain a sense of the strength of trade policy interdependence that is predicted by our theory, we provide a quantitative assessment of our findings by fitting our model to trade and production data from 40 major countries and 35 industries.[6] In this process we also demonstrate how our theory simplifies the quantitative analysis of trade policy reforms.

Our counterfactual analysis involves a hypothetical *gradual* trade policy reform that mimics the constraints introduced over time by the GATT and the WTO. Starting from each country's unconstrained optimal policy equilibrium, we introduce a sequence of partial restrictions on the government's policy space and quantify its optimal response with respect to unrestricted trade policy instruments. Importantly, we estimate that for the average country in our sample, the unconstrained optimal trade policy schedule imposes a negative *terms of trade* (ToT) externality of $12 billion on the rest of the world.

In the first sequence of liberalization, we introduce a ban on export policies, leaving all import tariffs at the discretion of the home government. This scenario

[6] We treat the European Union member countries as a single trade policy authority.

aligns with the GATT and WTO's more stringent restrictions on export subsidies versus import tariffs. The ban on export policy will induce the home government to decrease import tariffs uniformly across all industries. The US government, for example, is prompted to lower its tariffs from 59% to around 25% in response to the ban on export subsidies.[7] As a result of the export policy ban, the ToT externality of the average country's trade policy reduces by 62%. In comparison, a ban on import tariffs without restricting export policies will have no effect on the ToT externality.

The second sequence of liberalization retains the ban on all export policies, but also restricts import tariffs in half of the industries.[8] Such a restriction induces welfare-maximizing governments to lower their import tariffs on average by *a third* in unrestricted industries. This voluntary tariff reduction lowers the ToT externality of the average country's trade policy by another 33%. Therefore, a ban on export policies plus a partial ban on import tariffs lowers the ToT externality by a total of 95%.

The final sequence of liberalization bans all revenue-raising trade tax instruments. Welfare-maximizing government are, in this case, prompted to raise prohibitively-high NRTBs in select industries. However, for the average country, the ToT externality of these NRTBs amounts to only 3% of that imposed by the unconstrained optimal trade tax schedule.

The paper is organized as follows. After discussing the related literature in the subsequent Section, we begin by laying down our general framework in Section 3. In Section 4, we derive formulas for the optimal import and export tax/subsidy under a constrained policy space. Using these formulas, in Section 5, we analyze the interdependence of trade policies and the optimality of NRTBs. Section 6 presents

[7]The 59% import tariffs corresponds to the average Smoot-Hawley tariffs in the United States.

[8]For this partial liberalization experiment, we choose 50% of industries with the highest trade elasticities because tariffs in these industries have a bigger impact on trade.

our quantitative analyses. Finally, we provide concluding remarks in Section 7.

2 Related Literature

The existing literature is mostly silent about trade policy interdependencies due to its focus on "optimal" policy—rather than the tradeoffs that policymakers face outside the optimum—and partial equilibrium, which precludes interrelations across sectors. Partial exceptions include the literature on incomplete trade agreements and the literatures on tariff complementarity in Free Trade Areas and the Piecemeal Tariff Reforms, which we now discuss.

In a model of incomplete trade agreements, Horn, Maggi, and Staiger (2010) show that governments will have an incentive to use domestic subsidies in response to negotiated tariff cuts. The increase in domestic subsidies after entering a trade agreement tends to partially offset the benefits from negotiated trade liberalization.

While we find that tariffs across industries within a country are complementary, Richardson (1993), Bond, Riezman, and Syropoulos (2004) and Ornelas (2005) find that for members of a Free Trade Area (FTA), internal and external tariffs are complementary. In particular, they find that as a response to tariff cuts within an FTA, the member countries will voluntarily reduce their tariffs on imports from non-members. Similarly, in a North-South model, Zissimos (2009) considers tariff complementarities across countries within a region that compete for imports from the rest of the world.

The theory of piecemeal tariff reform (Hatta 1977; Fukushima 1979; Anderson and Neary 1992, 2007; Ju and Krishna 2000) is another strand of the literature that touches on the issue of policy interdependence. This literature is primarily concerned with welfare-enhancing tariff reforms that are revenue-neutral (or revenue-enhancing) in a small open economy. A general finding of the piecemeal reform literature is that compressing the variation of existing tariffs in developing countries—by reducing the highest tariff rates and increasing the lowest ones—could increase welfare without decreasing revenues. Although we focus on an entirely different problem in this paper, our finding about the optimality of uniform tariffs resonates with this literature's recommendation for tariff reforms.

As in this paper, Bagwell and Lee (2015) provide a perspective on the WTO's ban on export subsidies. Within a heterogenous-firm model, Bagwell and Lee (2015) show that if import tariffs (as well as transportation costs) are very low, then an export subsidy may benefit a country at the expense of its trading partners. Their finding suggests that a ban on export subsidies is useful only after substantial liberalizations have been reached through previous negotiations. By contrast, our analysis suggests that a ban on export subsidies is useful even without any restrictions on import tariffs.

Another related literature studies issue linkages in international relations. This literature considers various conditions under which there might be an interdependence between trade policies and non-trade policies—such as environmental policies (Ederington, 2001, 2002; Limão, 2005), production subsidies (Horn, Maggi, and Staiger, 2010), and intellectual property protection. These papers draw conclusions about whether these non-trade issues should be linked to trade agreements (see Maggi 2016 for a review).

Finally, the scope and focus of this paper differs from (Beshkar and Lashkaripour, 2020) in which we characterize the unilaterally optimal trade taxes under input-output linkages. Our theory is then applied to compute the Nash tariffs and the cost of dissolving the existing trade agreements in the presence of global values chains . In this paper, we abstract from input-output linkages to focus on the question of policy interdependence and the tradeoffs governments face under a constrained policy space. Needless to say, introducing input-output linkages will create new avenues for policy interdependence that are beyond the scope of this paper.

3 The Economic Environment

The world consists of two countries, $\mathbb{C} = \{h, f\}$, where h represents the Home country f represents an aggregate of the rest of the world. Country i is populated with L_i units of labor and hosts K industries, $\mathbb{K} = \{1, ..., K\}$. We impose no restrictions on the size or number of industries, so k can be alternatively viewed as an index that identifies narrowly-defined product categories. In each industry $k \in \mathbb{K}$, country $j \in \mathbb{C}$ produces a differentiated variety for a specific destination market, $i \in \mathbb{C}$. We index goods by ji, k (supplier j–destination i–industry k) to keep track of the origin, destination, and industry they correspond to.

Trade Policy Instruments The government in country i has three sets of trade policy instruments at its disposal: (i) industry-level export taxes/subsidies (denoted by $x_{ij,k}$); (ii) industry-level import taxes/subsidies (denoted by $t_{ji,k}$); and (iii) industry-level *non-revenue raising trade barriers* (NRTBs, denoted by $\tau_{ji,k}$) on imports. The last instrument accounts for red-tape barriers at the border or frivolous regulations that impede imports without raising revenue for the government.[9] These policy instruments create a wedge between the consumer price, $\tilde{p}_{ji,k}$, and

[9] In principle, NRTBs could be imposed on exports as well. Nevertheless, within our framework, such restrictions are never optimal and, hence, we do not consider them.

the producer price, $p_{ji,k}$, of each good ji,k as follows:

$$\tilde{p}_{ji,k} = \left(1 + t_{ji,k}\right)\left(1 + x_{ji,k}\right)\left(1 + \tau_{ji,k}\right) p_{ji,k}, \tag{1}$$

Moreover, these taxes raise the following revenues for the government in country i:

$$\mathcal{R}_i = \sum_{k\in\mathbb{K}} \sum_{j\in\mathbb{C}} \left[t_{ji,k}\left(1 + x_{ji,k}\right) p_{ji,k} q_{in,k} + x_{ij,k} p_{ij,k} q_{ij,k} \right]. \tag{2}$$

Throughout this paper, we assume that domestic policies are unavailable, i.e., $t_{ii,k} = x_{ii,k} = \tau_{ii,k} = 0$ for all i and k. Moreover, we sometimes use boldfaced notations, $\boldsymbol{t}_i, \boldsymbol{x}_i, \boldsymbol{\tau}_i$, to denote the respective policies of country i.

Technologies Firms are perfectly competitive and employ labor under constant returns to scale technologies. Labor is perfectly mobile across the production of different goods within the same county but immobile across countries. Let w_j the economy-wide wage rate paid to workers in Country j and let $a_{ji,k}$ denote the unit-labor requirement for the production and transportation of variety ji,k. The perfectly competitive *producer* price for variety ji,k is, thus , given by

$$p_{ji,k} = a_{ji,k} w_j. \tag{3}$$

Importantly, our assumption that labor is perfectly mobile and production exhibits constant returns to scale, ensures that $a_{ji,k}$ is constant and invariant to imposition of trade taxes.

Consumer Preferences The representative consumer in country i chooses the vector of consumption quantities, $\boldsymbol{q_i} \equiv \{q_{ji,k}\}$, to maximize a general utility function, $U_i\left(\boldsymbol{q_i}\right)$, subject to the budget constraint. The optimal choice of the consumers yields an indirect utility function,

$$\begin{aligned} V_i\left(Y_i, \tilde{\boldsymbol{p}}_{i,k}\right) \equiv \max_{\boldsymbol{q_i}} \quad & U_i\left(\boldsymbol{q_i}\right) \\ s.t. \quad & \sum_{k\in\mathbb{K}}\sum_{j\in\mathbb{C}} \tilde{p}_{ji,k} q_{ji,k} = Y_i, \end{aligned} \tag{4}$$

which summarizes social welfare as a function of total income, Y_i, and the vector of consumer prices $\tilde{\boldsymbol{p}}_i \equiv \{\tilde{p}_{ji,k}\}$ in country i. The corresponding Marshallian demand function is denoted by

$$\boldsymbol{q_i} = \mathcal{D}_i\left(\tilde{\boldsymbol{p}}_{\boldsymbol{i}}, Y_i\right).$$

The price and income elasticities associated with $\mathcal{D}_i\left(.\right)$ are denoted as follows.

D1. [***Marshallian Demand Elasticities***]

(i) [Own-price elasticity] $\varepsilon_{ji,k} \equiv \partial \ln q_{ji,k} / \partial \ln \tilde{p}_{ji,k}$;

(ii) [Cross-price elasticity] $\varepsilon_{ji,k}^{\jmath\iota,g} \equiv \partial \ln q_{ji,k} / \partial \ln \tilde{p}_{\jmath\iota,g}$ *for* $\jmath\iota, g \neq ji, k$;

(iii) [Income elasticity] $\eta_{ji,k} \equiv \partial \ln q_{ji,k} / \partial \ln Y_i$.

We restrict our attention to well-behaved demand functions that are continuous and locally non-satiated. We also assume that demand for each good exhibits an elastic region where $\mid \varepsilon_{ji,k} \mid > 1$. As in monopoly problems, this condition is necessary to obtain a bounded solution for optimal trade taxes.[10]

These product-level elasticity measures may be used to construct the a key aggregate-level elasticity, namely, the elasticity of Foreign demand for Home labor. Specifically, letting $L_{ji} = \mathcal{L}_{ji}\left(\boldsymbol{w}; \boldsymbol{t}, \boldsymbol{x}\right)$ denote country j's demand for country i's labor, we define wage-elasticity of labor demand as follows:

[10] As will become clear below, the problem of optimum tariff resembles a monopoly/monopsony problem.

D2. $\tilde{\varepsilon}_{ji} \equiv \frac{\partial \ln \mathcal{L}_{ji}(\boldsymbol{w};\boldsymbol{t},\boldsymbol{x})}{\partial \ln w_j} = \sum_k \sum_g \frac{\acute{r}_{ji,k}}{\acute{r}_{ji}} \varepsilon^{ji,g}_{ji,k}$.

In the above definition, the last equality follows from the Ricardian supply structure, which indicates that L_{ji}=$\sum_k q_{ji,k}/a_{ji,k}$. The elasticity of foreign demand for country j's labor reflects country j's collective export market power across all industries, which—as we show below—is a key determinant of j's optimal trade policy.

The importance of each good for taxation purposes is also affected by its share in expenditure and output. To streamline the presentation of our analysis, we define the expenditure and revenue shares for good ji,k as follows.

D3. ***[Expenditure and Revenue Shares]***

[*within-industry expenditure share*] $\lambda_{ji,k} \equiv \frac{\tilde{p}_{ji,k} q_{ji,k}}{\sum_{\jmath \in \mathbb{C}} \tilde{p}_{\jmath i,k} q_{\jmath i,k}}$

[*overall expenditure share*] $\acute{\lambda}_{ji,k} \equiv \frac{\tilde{p}_{ji,k} q_{ji,k}}{\sum_{\jmath \in \mathbb{C}} \sum_{g \in \mathbb{K}} \tilde{p}_{\jmath i,g} q_{\jmath i,g}}$.

[*within-industry **revenue** share*] $r_{ji,k} \equiv \frac{p_{ji,k} q_{ji,k}}{\sum_{\iota \in \mathbb{C}} p_{j\iota,k} q_{j\iota,k}}$

[*overall **revenue** share*] $\acute{r}_{ji,k} \equiv \frac{p_{ji,k} q_{ji,k}}{\sum_{\iota \in \mathbb{C}} \sum_{g \in \mathbb{K}} p_{j\iota,g} q_{j\iota,g}}$

Equilibrium. For a given vector of trade policy instruments, $\boldsymbol{x} \equiv \{x_{ji,k}\}$, $\boldsymbol{t} \equiv \{t_{ji,k}\}$, and $\boldsymbol{\tau} \equiv \{\tau_{ji,k}\}$, Equilibrium is a vector of consumption/production quantities, $\boldsymbol{q}_i$, producer prices, $\boldsymbol{p}_i$, consumer prices, $\tilde{\boldsymbol{p}}_i$, wage rates, $\boldsymbol{w}$, and income level, $\boldsymbol{Y}$, such that (i) consumption choices are a solution to 4: $\boldsymbol{q}_i = \mathcal{D}_i(Y_i, \tilde{\boldsymbol{p}}_i)$; (ii) producer prices are given by 3; (iii) consumer prices are given by 1; (iv) total income equals wage income plus tax revenue

$$Y_i = w_i L_i + \mathcal{R}_i,$$

where $\mathcal{R}_i$ is given by 2; and (v) wage income equals sales to all destinations net of taxes

$$w_i L_i = \sum_j \sum_i p_{ij,k} q_{ij,k}.$$

Condition (v) and the representative consumer's budget constraint ensure that trade is balanced.

For a given set of taxes, the quantities, $q_{ji,k}$, are uniquely determined under the equilibrium. However, as we know from the Lerner Symmetry Theorem, there are multiple sets of taxes that deliver the same equilibrium in real terms. To state the Lerner Symmetry Theorem formally, let $\boldsymbol{A} \equiv (\boldsymbol{1} + \boldsymbol{t}_i, \boldsymbol{1} + \boldsymbol{x}_i, \boldsymbol{t}_{-i}, \boldsymbol{x}_{-i}, \boldsymbol{\tau}; w_i, w_{-i})$ denote a wage-policy combinations that constitute an equilibrium. Then, for any $a \in \mathbb{R}_+$, $\boldsymbol{A}' \equiv (a(\boldsymbol{1} + \boldsymbol{t}), (\boldsymbol{1} + \boldsymbol{x})/a, \boldsymbol{t}_{-i}, \boldsymbol{x}_{-i}, \boldsymbol{\tau}; aw_i, w_{-i})$ constitutes an equilibrium that is identical to A in real terms, namely, all the quantities and, hence, welfare of both countries, are identical under A and A'.

An immediate corollary of the Lerner symmetry is that there are multiple optimal tax schedules as long as both export and import taxes are applicable. That is, for any optimal tax schedule, a uniform shift in all export and import taxes preserves optimality. However, once the policy space is partially restricted, the optimal (second-best) tax schedule is unique.

Throughout this paper we focus on cases where only the Home country actively uses trade policy instruments, $t_{fh,k}$, $x_{hf,k}$, and $\tau_{fh,k}$, while Foreign follows a passive Laissez-Faire policy, i.e., $x_{fh,k} = t_{hf,k} = \tau_{hf,k} = 0$ for all k. We can, therefore, simplify the notation by dropping country indexes from trade policy variables.

Specifically, we use

$$\begin{cases} t_k \equiv t_{fh,k}, \\ x_k \equiv x_{hf,k}, \\ \tau_k \equiv \tau_{fh,k}. \end{cases}$$

Accordingly, the vectors $\boldsymbol{t} = \{t_k\}$, $\boldsymbol{x} = \{x_k\}$, and $\boldsymbol{\tau} \equiv \{\tau_k\}$ denote the vector of Home's trade policy instruments, hereafter.

4 Constrained-Optimal Policies

The government's policy space may be partially restricted by various domestic laws or international treaties. For example, the United State Constitution prevents the government from imposing export taxes. Moreover, trade agreements have imposed partial restrictions on the member governments' policy space. Under the WTO, for example, while governments agreed to implement tariff cuts on some products, they retained flexibility in setting import tariffs on other products.[11]

To analyze the response of the governments to partial liberalization, we begin in this section by characterizing the optimal rate of tax/subsidy on a trade flow, taking taxes and subsidies on all other trade flows as given.[12] In particular, solving the optimization problem $t_k^*(\boldsymbol{t}_{-k}, \boldsymbol{x}, \boldsymbol{\tau}) = \arg\max_{t_k} \quad W_h\left(t_k; \boldsymbol{t}_{-k}, \boldsymbol{x}, \boldsymbol{\tau}\right)$, yields the optimal import tariffs on product k as follows:

Proposition 1. *The optimal export and import tax on product k can be expressed as the*

[11] See Beshkar et al. (2015); Beshkar and Bond (2017) for an analysis of flexibility in trade agreements.

[12] When revenue-raising taxes are available, the optimal NRTB is trivially equal to zero, $\tau_k^* = \mathbf{0}$. We will analyze the optimality of NRTB in the absence of revenue-raising taxes in Section 5.3.

following function of applied taxes on other products

$$1+t_k^* = (1+\Upsilon\bar{\tau})\left(1-\sum_{g\neq k}\left[\left(\frac{1+t_g}{1+\Upsilon\bar{\tau}}-1\right)\frac{\lambda_{fh,g}\varepsilon_{fh,g}^{fh,k}}{\lambda_{fh,k}\varepsilon_{fh,k}}\right]\right)\left(1+\frac{1-\Upsilon}{\varepsilon_{fh,k}}\right)^{-1}, \quad (5)$$

and

$$1+x_k^* = \frac{\varepsilon_{hf,k}}{1+\varepsilon_{hf,k}\left[1+\sum_{g\neq k}\left(1-\frac{1}{(1+x_g)(1+\Upsilon\bar{\tau})}\right)\frac{\acute{\lambda}_{hf,g}}{\acute{\lambda}_{hf,k}}\frac{\varepsilon_{hf,g}^{hf,k}}{\varepsilon_{hf,k}}\right]}(1+\Upsilon\bar{\tau})^{-1}, \quad (6)$$

where, $\Upsilon \equiv \frac{1-\sum_g\left(\frac{t_g}{1+t_g}\lambda_{fh,g}\eta_{fh,g}\right)}{1-\sum_g\left(\frac{\bar{\tau}}{1+t_g}\lambda_{fh,g}\eta_{fh,g}\right)}$ *denotes the aggregate income elasticity,* $1+\bar{\tau} \equiv \frac{(1+\bar{t})\tilde{\varepsilon}_{fh}+(1+\bar{x})^{-1}\tilde{\varepsilon}_{hf}}{1+\tilde{\varepsilon}_{hf}+\tilde{\varepsilon}_{fh}}$, $1+\bar{x} \equiv \sum_k\left[\frac{\acute{r}_{fh,k}}{\acute{r}_{fh}}(1+x_k)\right]$, *and* $1+\bar{t} \equiv \sum_k\left[(1+t_k)\frac{\acute{r}_{fh,k}}{\acute{r}_{fh}}\frac{\tilde{\varepsilon}_{fh,k}}{\tilde{\varepsilon}_{fh}}\right]$.

Optimal tax formulas 5-6 indicate three channels through which different tax instruments are interdependent: (i) income effects, (ii) wages effects, and (iii) cross-industry demand effects. Income effects operate through the uniform term, Υ, which reflects the income elasticity of Home's aggregate import demand. This term disappears from the optimal trade tax formulas when traded goods are income inelastic, i.e., $\Upsilon = 1$. Otherwise, a change in trade taxes in industry g affects tax revenues and income in the Home country. These effect in turn alter the marginal revenue collectable from trade taxes in all other industries ($k \neq g$).

Wage effects concern the ability of trade taxes to raise Home's wage relative to Foreign (i.e., w_h/w_f). This terms-of-trade-improving ability demands a uniform tax on exports and imports, which is encapsulated in the term $\bar{\tau}$. Accordingly, $\bar{\tau} = 0$ if wages are assumed to be invariant to policy, as is standard in the trade policy literature.[13] Beyond this special case, wage effects create interdependence

[13]The trade policy literature often eliminates general-equilibrium wage effects by assuming a sufficiently large *homogeneous* sector that is costlessly traded—see Maggi (2014).

between trade tax instruments as follows: A change in industry g's trade taxes modifies $\bar{\tau} = \bar{\tau}(\boldsymbol{t}, \boldsymbol{x})$. Subsequently, and as implied by Proposition 1, the optimal tax choice in any industry $k \neq g$ will change with $\bar{\tau}$. The intuition is that the marginal effect of t_k or x_k on w_h / w_f (and their optimal rate, t_k^*, or x_k^*) is a function of applied taxes in industry $g \neq k$.

Cross-demand effects operate through the cross-demand elasticities, $\varepsilon_{fh,g}^{fh,k}$, and $\varepsilon_{hf,g}^{hf,k}$. With zero cross-substitutability between industries, $\varepsilon_{fh,g}^{fh,k} = \varepsilon_{hf,g}^{hf,k} = 0$, the summation terms that appear in the expressions for t_k^* and x_k^* collapse to zero. If industries are gross substitutes, a reduction in industry k's trade taxes decreases the trade tax base in other industries. Therefore, as will be discussed more formally in Section 5.2. , negotiated tariff cuts in a subset of industries will prompt the governments to cut their tariffs in unrestricted industries unilaterally.

Unconstrained Optimal Policy

Solving Equations 5-6 simultaneously for all industries yields optimal import and export tax/subsides when the policy space is unconstrained. Doing so, as shown in Appendix A.1, implies a uniform optimal import tax equal to $\bar{\tau}$ and an optimal export tax as follows:

$$\begin{aligned} 1 + t_k^* &= 1 + \bar{\tau}, \\ 1 + x_k^* &= \frac{\varepsilon_{hf,k}}{1 + \varepsilon_{hf,k} + \xi_{hf,k}} (1 + \bar{\tau})^{-1}, \end{aligned} \tag{7}$$

where

$$[\xi_{hf,k}]_k = \left[\left[\frac{\acute{\lambda}_{hf,g} \varepsilon_{hf,g}^{hf,k}}{\acute{\lambda}_{hf,k} \varepsilon_{hf,g}} \right]_{k,g}^{-1} - \boldsymbol{I} \right] \mathbf{1}$$

accounts for cross-price elasticity effects between industries.[14]

The above optimal export tax formula in 7 resembles the mark-up pricing of a multi-product monopolist. The variation of optimal export taxes across products are determined by demand-side parameters, in a way that is similar to the variation of monopoly mark-ups in a multi-product monopoly problem. In particular, the optimal export tax on a product is lower if the country exports other products that are closely substitutable. Our analysis, however, differs from a pure monopoly problem as it incorporates general-equilibrium effects on wages and income, as well as linkages between the monopolist problem (i.e., export policies) and the monopsonist problem (i.e., import policies) that are not considered in the standard multi-product monopoly problem. Note that with zero cross-substitutability between industries, $\Xi = \boldsymbol{I} \iff \xi_{hf,k} = 0$, the optimal tax formula reduces to $x_k^* = \varepsilon_{hf,k} / \left(1 + \varepsilon_{hf,k}\right)$, which is familiar from the optimal trade policy literature that focuses on a model with one export good and one import good.

The Lerner Symmetry is evident from the optimal trade policy formula (7). In particular, any uniform tariff rate on all products (including zero tariffs) could be part of a unilaterally optimal trade policy schedule. We will use this result in the next Section to argue that compared to a ban on import taxes, a constraint on export taxes/subsidies will impose a stricter limit on the governments' ability to manipulate the terms of trade.

The formula specified above is obtained under general preferences and may be applied to an environment with arbitrarily many industries or a continuum of goods ła Dornbusch et al. (1977). In that regard, the above characterization generalizes the optimal trade tax formulas in Costinot et al. (2015) and Opp (2010).[15]

[14] $\mathbf{1}$ is a $K \times 1$ vector of ones and $\boldsymbol{I}$ is the $K \times K$ identity matrix.

[15] See Appendix A.2 for further details.

This formula, however, is a special case of Beshkar and Lashkaripour (2020) in which we consider input-output linkages across industries and countries. As we show in that paper, the optimality of uniform tariffs extends to a case with trade in intermediate inputs as long as export policy is also freely available to the policymakers.

5 Interdependence of Trade Policies

Trade policy interdependence concerns the effect of policy choices or restrictions in one area on the tradeoffs that policymakers face in other areas. Political considerations, domestic regulations, and international trade agreements may limit the government's flexibility in choosing their trade policy. In the presence of general-equilibrium linkages, these partial restrictions can influence the government's choice of optimal policy with respect to unrestricted instruments.

In this section, we characterize policy interdependence by introducing various restrictions on the government's policy space and re-optimizing the policy problem to find the government's optimal response in the free instruments. We introduce the restrictions on the policy space in a sequence that reflects the observed gradualism in the GATT/WTO pattern of liberalization over time. First, in Subsection 5.1, we introduce a ban on export policy and determine the government's optimal response in the use of import policy. This experiment is designed to reflect the GATT/WTO's expansive ban on export subsidies and the domestic institutional constraints on export taxes in many countries.

We then characterize the optimal response of the government to an additional ban on import tariffs in a subset of sectors. This scenario resembles the partial restrictions on import tariffs under the WTO. The tariff caps negotiated under the

GATT/WTO vary substantially across sectors and countries. Under these tariff caps, the WTO members had the flexibility to raise tariffs unilaterally on more than 32% of trade flows among them.[16]

Finally, we consider a scenario in which all observable import and export policies (i.e., taxes and subsidies) are negotiated away but the government's have the ability to erect hidden trade barriers.

Before moving forward, not that per the discussion under Equation 7, the unconstrained optimal policy includes uniform (or zero) import taxes. So, if all import taxes are restricted, the unconstrained optimal outcome can be restored with a uniform shift in all export taxes. In other words, restricting import taxes alone has no real effect on the level of protection.

5.1 Optimal Response to a Ban on Export Policies

Suppose the Home government enters an *incomplete* trade agreement that prohibit export taxes/subsides in all industries, but leaves import taxes to the discretion of the government.[17] To determine the optimal import tax under such an agreement, we can appeal to optimal import tariff formula (5) by setting $\boldsymbol{x} = \mathbf{0}$, and simultaneously solving the system of equations characterizing t_k^* for all industries. Doing so implies that the optimal import tariff response is to apply a uniform but non-zero import tariff.

Proposition 2. *When export taxes/subsidies are banned but import tariffs are left to the discretion of the Home government, the optimal import tariffs are uniform across products*

[16]See Beshkar et al. (2015) and Beshkar and Lee (Beshkar and Lee) for empirical evidence on unilateral flexibility in setting import tariffs under the WTO.

[17]Alternatively, consider a situations where export subsidies are banned by a trade agreement (as under GATT/WTO) and export taxes are banned by domestic regulations (as in the United States.)

and are given by

$$1 + \bar{t}^* = \frac{\tilde{\varepsilon}_{hf}}{1 + \tilde{\varepsilon}_{hf}}. \tag{8}$$

This Proposition points to a rather surprising corollary. Given the Lerner symmetry, Proposition 2 implies that the optimal import tax has an effect that is equivalent to a uniform export tax. But the non-uniformity of optimal export taxes implies that welfare under optimal export tax is higher than welfare under any combination of import tariffs. In other words, import tariffs are an imperfect substitute for export taxes, whereas export taxes can perfectly reproduce any welfare level that is attainable with import tariffs. Formally,

Corollary 1. *Banning export policies while leaving import tariffs discretionary will reduce the degree of trade restrictions chosen by the government. In contrast, banning import tariffs while leaving export policies discretionary will have no impact on the level of trade restrictions chosen by the government.*

Intuitively, this result is obtained because import tariffs can manipulate Home's terms of trade only through their effect on relative wages, but export taxes could also improve terms of trade both by affecting wages and by directly affecting the consumption price of the exported goods for foreign consumers.

Corollary 1 offers a novel perspective on the WTO's ban on export subsidies. As reviewed by Lee (2016), the terms-of-trade literature has found it "quite difficult to justify the prohibition of export subsidies given the trade-volume-expanding nature of export subsidies." In contrast, we find that even within a terms-of-trade framework, a ban on export subsidies is welfare improving due to the interdependence of import and export policies in a general-equilibrium framework. To be specific, if pre-GATT policies of the governments involved high export subsidies and import tariffs, Corollary 1 implies that banning export subsidies will spur unilateral tariff cuts to a degree that leads to an overall increase in trade volumes.

The above corollary relies on the Ricardian assumption that the unit labor cost is invariant to taxes. This assumption may appear strong, but it is backed by recent evidence from the US-China trade war. Amiti et al. (2019) and Fajgelbaum et al. (2020) have documented that, conditional on economy-wide wage or price effects, the US tariffs have been completely passed on to the US consumers. This observation is consistent with a constant unit labor cost assumption.

5.2 Optimal Response to Partial Tariff Cuts

Now, we consider a second sequence of liberalization in which in addition to a ban on export policy, import taxes are also banned in a *subset* of industries. As we discussed above, this scenario is meant to mimic the partial tariff cuts that were the result of various rounds of negotiations under the GATT. To simplify the analysis, we consider a binary case in which tariffs on some products are set to zero by the agreement while other tariff lines are left to the discretion of the governments. The main result of this subsection will extend to a situation where negotiated tariffs show more variation across products. Moreover, to focus on the role of general-equilibrium wage effects and cross-product substitutability, in this subsection we assume that traded industries exhibit a zero or negligible income elasticity, i.e., $\Upsilon \approx 1$.[18] Under this assumption, the optimal import tariff formula (2) for unliberalized products may be rewritten as:

$$1 + t_k^* = (1 + \bar{t}) \left(1 + \sum_{g \neq k} \left[\left(\frac{1 + t_g}{1 + \bar{t}} - 1 \right) \frac{\acute{r}_{fh,g} \varepsilon_{fh,g}^{fh,k}}{\acute{r}_{fh,k} \varepsilon_{fh,k}} \right] \right), \quad k \in \mathbb{K}_L, \tag{9}$$

[18] This assumption is consistent with a quasi-linear utility aggregator across industries, with trade costs being prohibitively high in the linear industry.

where, $\mathbb{K}_L$ denotes the set of unrestricted industries, and $\bar{t}$ is a uniform term that accounts for general-equilibrium wage effects:

$$1 + \bar{t} = \frac{\tilde{\varepsilon}_{hf} + \sum_g \left[\left(t_g - \bar{t} \right) \frac{\acute{r}_{fh,g}}{\acute{r}_{fh}} \tilde{\varepsilon}_{fh,g} \right]}{1 + \tilde{\varepsilon}_{hf}}. \tag{10}$$

It is evident from this formula that when tariffs in a subset of products are set to zero exogenously, the optimal tariff on unrestricted products are no longer uniform. Moreover, as we show in the proof of the following Proposition, under mild conditions, the optimal response of the government to negotiated tariff cuts in a subset of products is to cut tariffs in unrestricted sectors. Specifically,

Proposition 3. *If $\partial \mid \tilde{\varepsilon}_{hf} \mid / \partial w_h$ is sufficiently small and industries are gross substitutes, then tariffs are complementary across industries.*

Tariff complementarity operates through two distinct channels. First, tariff cuts in a subset of sectors lead to a decrease in the relative wage of the Home country, which lead to a decline in $\bar{t}$. Noting that $\tilde{\varepsilon}_{fh,g} < 0$, if $\partial \mid \tilde{\varepsilon}_{hf} \mid / \partial w_h$ is sufficiently small we must have

$$\bar{t}^P \equiv \frac{\tilde{\varepsilon}^P_{hf} + \sum_g \left[\left(t^P_g - \bar{t}^P \right) \frac{\acute{r}^P_{fh,g}}{\acute{r}_{fh}} \tilde{\varepsilon}^P_{fh,g} \right]}{1 + \tilde{\varepsilon}^P_{hf}} < \bar{t} \equiv \frac{\tilde{\varepsilon}_{hf}}{1 + \tilde{\varepsilon}_{hf}},$$

where the superscript P refers to variables under partial liberalization, and variables without this superscript correspond to the case of optimal tariffs across all products.[19]

A second driver of tariff complementarity arises when industries are gross substitutes, i.e., $\varepsilon^{fh,k}_{fh,g} > 0$ for all k and g. In that case, the second parenthesis in Equa-

[19]To ensure that $\bar{t}$ reduces in response to partial liberalization, we need $\partial \mid \tilde{\varepsilon}_{hf} \mid / \partial w_h$ to be suf-

tion 9 is equal to unity when all tariffs are set optimally, and smaller than unity otherwise. Hence, partial liberalization reduces the unilaterally optimal import tariffs in unrestricted products through cross-elasticity effects. For an intuition for this result note that tariff cuts in a subset of products decreases the import volume of products that are still subject to higher import tariffs. By reducing tariffs on unliberalized products, the government could reallocate some import demand from zero-tariff products to positive-tariff products, thereby generating more tariff revenues and improving its terms of trade.

As we will argue in our Concluding Remarks, in light of the tariff complementarity result (Proposition 3), we may argue that an incomplete trade agreement may be optimal if tariff cut negotiations are costly and these costs are increasing in the number of tariff lines included in negotiations

5.3 Optimality of Non-Revenue Trade Barriers

Finally, we consider the last stage in the liberalization process where all revenue-raising trade policy instruments are restricted. In this case, the Home government may be able to erect *hidden* non-revenue trade barriers (NRTBs) that restrict imports without generating any revenues. It is well known that under standard *partial-equilibrium* or *one-industry general-equilibrium* trade policy models, there are no gains from erecting NRTBs. However, in our multi-industry general-

ficiently small. That is, the decline in w_h/w_f due to partial liberalization, should not lead to a too large of a decline in $\mid \tilde{\varepsilon}_{hf} \mid$. This will the case if the demand for labor is sufficiently concave. Generally, in our multi-industry framework, two factors affect the convexity of demand for labor. On the one hand, a drop in w_h alters the composition of demand in favor of high-elasticity industries. This effect always contributes to a lower $\partial \ln \mid \tilde{\varepsilon}_{hf} \mid / \partial w_h$. On the other hand, a drop in w_h can also alter the demand elasticity level, $\varepsilon_{hf,k}$, per industry, with the direction of this latter change depending on the underlying demand function. Considering this, Proposition 3 simply holds if composition effects are sufficiently large. Later in Section 6, we show that in a standard multi-industry gravity model fitted to data, the conditions outlined by Proposition 3 are satisfied, and that industry-level import taxes exhibit strong complementarity.

equilibrium framework, we find that NRTBs could improve the Home country's welfare at the expense of the Foreign country.

We model NRTBs as wasteful iceberg transport costs that do not generate revenues for the government or utility for consumers.[20] The government's problem is to choose product-specific NRTBs, $\{\tau_k\}$ to maximize its welfare.[21] We find that optimal NRTBs are (i) strictly positive in industries where demand for imports from Foreign is sufficiently elastic, and (ii) zero in other industries (see Appendix D). Moreover, if $\varepsilon_{fh,k}$ is non-decreasing in $q_{fh,k}$, the optimal NRTB is prohibitively large in high-ε industries.[22] That is,

$$\tau_k^* = \begin{cases} \infty & \text{if} \quad \varepsilon_{fh,k} < 1 + \tilde{\varepsilon}_{hf} + \tilde{\varepsilon}_{fh} \\ 0 & \text{if} \quad \varepsilon_{fh,k} > 1 + \tilde{\varepsilon}_{hf} + \tilde{\varepsilon}_{fh} \end{cases}, \tag{11}$$

where, as earlier, $\tilde{\varepsilon}_{ji}$ denotes the elasticity of labor demand, which is weighted average of industry-level demand elasticities. The above formula indicates that in a single-industry model, the optimal NRTB is always zero since $\varepsilon_{fh,k} = \tilde{\varepsilon}_{fh} > 1 + \tilde{\varepsilon}_{fh} + \tilde{\varepsilon}_{hf}$. Similarly, the optimal NRTB will be zero in all industries if wages where assumed to be invariant to policy as in partial-equilibrium models. But once we accommodate general-equilibrium wage effects and allow for multiple industries, there is an incentive for setting NRTBs, which is summarizes by the following proposition.

Proposition 4. *Absent revenue-raising taxes, it is optimal to impose a prohibitively high*

[20] Import quotas and voluntary export restraints could also be considered non-revenue trade barriers, but both are restricted under trade agreements. We focus on wasteful iceberg transport costs to better represent hidden trade barriers such as border red-tapes and frivolous regulations.

[21] Stated formally, the optimal NRTBs, $\boldsymbol{\tau}$, are chosen to maximize $W_h(\mathbf{0}, \mathbf{0}, \boldsymbol{\tau}; \boldsymbol{w})$ subject to $(\mathbf{0}, \mathbf{0}, \boldsymbol{\tau}; \boldsymbol{w}) \in \mathbb{A}$.

[22] The condition that $\partial\varepsilon_{fh,k}/\partial q_{fh,k} \geq 0$ is widely-known as Marshall's Second Law of Demand, and is satisfied in an important class of trade models.

NRTB on imports with sufficiently high demand elasticities. The optimal NRTB on all other imports and exports will be zero.[23]

There is a simple logic behind the above result. Erecting NRTBs on a subset of products reduces the Home consumers' welfare with respect to those products, but improves Home's terms of trade with respect to all other imports. In high-ε industries, the gains from importing Foreign varieties are relatively small, because a high ε indicates strong substitutability between imported and domestic varieties. On the other hand, restricting imports in high-ε industries can reduce foreign wages and, as a result, the price of imports in all other product categories. These general-equilibrium wage effects can be large enough to offset the modest welfare loss due to a price increase in the NRTB-restricted industries.

6 Quantitative Analysis

In this section, we map our theoretical model to industry-level trade and production data to evaluate the quantitative significance of the trade policy interdependence outlined by Corollary 1 and Propositions 3 and 4.

6.1 Mapping Theory to Data

To map our theory to data we need to impose some parametric structure on the demand-side of the economy. To this end, as in Costinot et al. (2012), we assume that preferences have a Cobb-Douglas CES structure, namely, $U_i(\boldsymbol{q_i}) = \prod_k \left(\sum_j \alpha_{ji,k}^{1-\rho_k} q_{ji,k}^{\rho_k}\right)^{e_{i,k}/\rho_k}$, where $\alpha_{ji,k}$ is a constant utility shifter and $e_{i,k}$ denotes the constant share of expenditure on industry k, with $\sum_k e_{i,k} = 1$. The associated indi-

[23]Proof is provided in Appendix D.

rect utility will be given by $V\left(Y_i, \tilde{P}_i\right) = Y_i/\tilde{P}_i$, where $\tilde{P}_i$ denotes the aggregate price index in economy $i \in \mathbb{C}$,

$$\tilde{P}_i = \prod_{k\in\mathbb{K}} \left(\sum_{j\in\mathbb{C}} \alpha_{ji,k} \tilde{p}_{ji,k}^{-\epsilon_k} \right)^{-e_{i,k}/\epsilon_k}, \tag{12}$$

and $\epsilon_k \equiv \rho_k / (1-\rho_k)$ denotes the industry-level trade elasticity. Correspondingly, the within-industry expenditure share on variety ji, k is given by

$$\lambda_{ji,k} = \frac{\alpha_{ji,k}\tilde{p}_{ji,k}^{-\epsilon_k}}{\sum_{\ell\in\mathbb{C}} \alpha_{\ell i,k}\tilde{p}_{\ell i,k}^{-\epsilon_k}} \quad \forall j, i \in \mathbb{C}, \tag{13}$$

which implies the following demand elasticity formulas: $\varepsilon_{ji,k} = -1 - \epsilon_k \lambda_{ii,k}$; $\varepsilon_{ji,k}^{ii,k} = \epsilon_k \lambda_{ii,k}$ if $j \neq i$; $\varepsilon_{ji,k}^{ji,g} = 0$ if $g \neq k$; and $\eta_{ji,k} = 1$ for all ji, k.

Consider a counterfactual policy change, whereby the vector of trade taxes changes from its applied rate, $\{t_{ij,k}\}$, and $\{x_{ji,k}\}$, to a counterfactual rate, $\{t'_{ij,k}\}$, and $\{x'_{ji,k}\}$. Denote this tax change using the conventional hat-algebra notation as

$$\widehat{1+t_{ji,k}} = (1+t'_{ji,k})/(1+t_{ji,k}),$$
$$\widehat{1+x_{ji,k}} = (1+x'_{ji,k})/(1+x_{ji,k}).$$

The above tax change will trigger a change in (i) expenditure shares, $\hat{\lambda}_{ji,k} = \lambda'_{ji,k}/\lambda_{ji,k}$, (ii) wages $\hat{w}_i = w'_i/w_i$, and (iii) total income, $Y_i = Y'_i/Y_i$, in each country. These changes can be determined by solving the following system of equations that combines the labor market clearing condition (LMC) with the representative consumer's budget constraint (BC), all expressed in hat-algebra notation:

$$
\begin{aligned}
&\hat{\lambda}_{ji,k} = \left[\hat{w}_j\ (\widehat{1+t_{ji,k}})(\widehat{1+x_{ji,k}})\right]^{-\epsilon_k} \hat{\tilde{P}}_{i,k}^{\epsilon_k}, \\
&\hat{\tilde{P}}_{i,k}^{-\epsilon_k} = \sum_j \left(\left[\hat{w}_j(\widehat{1+t_{ji,k}})(\widehat{1+x_{ji,k}})\right]^{-\epsilon_k} \lambda_{ji,k} \right), \\
&\hat{w}_i w_i L_i = \sum_k \sum_j \left[\hat{\lambda}_{ij,k}\lambda_{ij,k} e_{j,k} \hat{Y}_j Y_j / (1+x'_{ij,k})(1+t'_{ij,k})\right], \qquad \text{[LMC]} \\
&\hat{Y}_i Y_i = \hat{w}_i w_i L_i + \sum_k \sum_j \left(\frac{t'_{ji,k}}{1+t'_{ji,k}} \hat{\lambda}_{ji,k}\lambda_{ji,k} e_{i,k} \hat{Y}_i Y_i + \frac{x'_{ij,k}}{1+x'_{ij,k}} \hat{\lambda}_{ij,k}\lambda_{ij,k} e_{j,k} \hat{Y}_j Y_j \right). \qquad \text{[BC]}
\end{aligned}
\tag{14}
$$

After solving the above system, the welfare consequences of the tax change can be calculated as

$$
\hat{W}_i = \hat{Y}_i / \prod_k \hat{\tilde{P}}_{i,k}^{e_{i,k}}.
$$

We provide a quantitative analysis of sequential liberalization and the associated unilateral policy adjustments that was discussed in Section 5. Liberalization occurs sequentially: In the first stage, export taxes and subsidies are eliminated. In the second stage, a subset of import taxes are eliminate. In the third stage, the remaining import tariffs are also eliminated, while the government could still impose hidden trade barriers/NRTBs.

Pre-liberalization: ***Unconstrained Optimal Policy.*** When there are no constraints on the Home government's policy space, Proposition 1 implies that Home's unconstrained optimal policy will include a uniform import tariff, $\bar{t}$, paired with and an industry-specific export tax, $1 + x^*_{hf,k} = \left(\frac{\varepsilon_{hf,k}}{1+\varepsilon_{hf,k}}\right)(1+\bar{t})^{-1}$. Given that $\varepsilon_{hf,k} = -1 - \epsilon_k \lambda_{ff,k}$, the optimal export tax can be alternatively expressed as $1 + x^*_{hf,k} = \left(1 + \frac{1}{\epsilon_k \lambda_{ff,k}}\right)(1+\bar{t})^{-1}$. Considering this, we can determine the welfare consequences of Home's optimal policy by considering an import tax change, $\widehat{1+t_{fh,k}} = (1+\bar{t})/(1+t_{fh,k})$, paired with an export tax change, $\widehat{1+x_{hf,k}} = (1+x'_{hf,k})/(1+x_{hf,k})$, where

$$1+x'_{hf,k} = \left(1+\frac{1}{\epsilon_k \lambda_{ff,k} \hat{\lambda}_{ff,k}}\right)(1+\bar{t})^{-1}.$$

Solving the above equation in combination with the system of equations specified under 14 determines the $\hat{W}_h$ and $\hat{W}_f$ that result from this tax change. Note that by Lerner symmetry, the choice of $\bar{t}$ is redundant for welfare consequences. To handle this redundancy, we choose a value of $\bar{t} = 0.59$ to match the average Smoot–Hawley tariff rates, which are considered as non-cooperative tariffs for the United States.

Stage 1 of Liberalization: ***Export Taxes/Subsidies are Banned.*** When all export policy instruments are banned, Proposition 2 implies that the optimal tariff will be $1+t^*_{fh} = \tilde{\varepsilon}_{hf}/(1+\tilde{\varepsilon}_{hf})$, which under the CES-Cobb-Douglas demand system reduces to $t^*_{fh,k} = 1/\sum_g \left(\frac{r_{fh,g}}{r_{fh}} \epsilon_g \lambda_{ff,g}\right)$. So, the consequences of Home applying this tariff schedule can be determined as the effect of a tax change, $\widehat{1+t_{fh,k}} = (1+t'_{fh,k})/(1+t_{fh,k})$, where

$$t'_{fh,k} = \frac{1}{\sum_k \chi_{fh,k} \epsilon_k \lambda_{ff,k} \hat{\lambda}_{ff,k}}$$

with $\chi_{fh,k} \equiv \frac{\hat{r}_{fh,g} r_{fh,g}}{\hat{r}_{fh} r_{fh}} = \frac{\hat{\lambda}_{ij,k} \lambda_{ij,k} e_{j,k} Y_j}{\sum_g \hat{\lambda}_{ij,g} \lambda_{ij,g} e_{j,g} Y_j}$. As before, solving the above equation in combination with the system of equations specified under 14 determines $\hat{W}_h$ and $\hat{W}_f$. Comparing the $\hat{W}_f$ implied by this tariff schedule to that implied by the unconstrained optimal tax schedule determines how that ban on export subsidies reduces the burden of Home's policy on the rest of the world.

Stage 2 of Liberalization: ***In addition to Export Taxes/Subsidies, Import Tariffs are Banned in a Subset of Industries.*** Suppose that in addition to export policies, import tariffs are also banned in a subset of industries, namely, $\mathbb{K}_R$. In that case, Home's optimal tariffs in unrestricted industries ($\mathbb{K}_L = \mathbb{K} - \mathbb{K}_R$) are characterized by Proposition 1. Noting the Cobb-Douglas-CES demand specification, the effect of such tariffs can be determined as a tax change, $\widehat{1+t}_{fh,k} = (1+t'_{fh,k})/(1+t_{fh,k})$, where $\widehat{1+t}_{fh,k} = 1$ if $k \notin \mathbb{K}_L$ and

$$1 + t'_{fh,k} = (1+\tau\Upsilon)\left(1 + \frac{\Upsilon - 1}{1 + \epsilon_k \hat{\lambda}_{hh,k}\lambda_{hh,k}}\right)^{-1} \quad \forall k \in \mathbb{K}_L,$$

with the uniform terms, Υ, and τ, given by

$$\Upsilon - 1 = \frac{\sum_g \frac{t'_g - \tau}{1+t_g}\hat{\lambda}_{fh,g}\lambda_{fh,g}}{1 - \sum_g \frac{\tau}{1+t_g}\hat{\lambda}_{fh,g}\lambda_{fh,g}},$$
$$1 + \tau = \frac{\sum_k \left(1+t'_k\right)\left(1 + \epsilon_k \lambda_{hh,k}\hat{\lambda}_{hh,k}\right)\chi_{fh,k}}{1 + \sum_k \chi_{hf,k}\epsilon_k\lambda_{ff,k}\lambda_{ff,k} + \chi_{fh,k}\epsilon_k\lambda_{hh,k}\lambda_{hh,k}}.$$

As before, $\hat{W}_h$ and $\hat{W}_f$ can be determined by solving the above three equations in combination with the system of equations specified under 14. Comparing $\hat{W}_f$ under this policy and the unconstrained policy determines how the partial ban on import tariffs further reduces the burden of Home's trade policy on the rest of the world.

Stage 3 of Liberalization: ***All Import and Export Taxes/Subsidies are Banned.*** When all revenue-raising taxes are banned, the Home government will raise prohibitively-high NRTBs in some industries. We can use the conditions outlined by Equation 11 to identify these industries. Alternatively, we can identify these industries by searching for NRTBs that maximize Home's welfare subject to equilibrium constraints. This latter approach combines MPEC (Mathematical Programming with Equilibrium Constraints) with the already-discussed hat-algebra technique. Unlike prior stages, there is no particular advantage from using either approach. We adopt the latter, which is widely-used in the prior literature (e.g., Ossa 2014).

6.2 Data

To evaluate the equations specified in the previous section, we need data on $\lambda_{ji,k}$, $e_{i,k}$, Y_i, and $w_i L_i$. We take this data from the 2012 edition of the World Input-Output Database (WIOD, Timmer et al. 2012). The WIOD database covers 35 industries and 40 countries, which account for more than 85% of world GDP, plus an aggregate of the rest of the world. The countries in the sample include all 27 members of the European Union and 13 other major economies, namely, Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey, and the United States. The 35 industries in WIOD database include 15 tradable industries and 20 service-related industries—see Tables 2 and 3 for a thorough description of countries and industries used in the analysis. To be consistent with our analytical framework, we restructure the WIOD database in two dimensions. First, we merge all the service industries into a single aggregated non-traded sector. Second, we purge the data from trade imbalances. In this process, we closely follow the methodology in Costinot and Rodríguez-Clare (2014), who apply Dekle et al.'s (2007) hat-algebra methodology to purge the 2008 edition of the WIOD.[24]

[24] A similar approach is also applied by Ossa (2014) to eliminate trade imbalances from the GTAP database.

Considering the structure of the WIOD data, we treat ij,k as a good pertaining to WIOD industry k that is supplied by country i to market j. Also, as in Costinot and Rodríguez-Clare (2014), we assume that the status-quo is free trade—that is, the WIOD data corresponds to a state of the economy where $t_{ji,k} \approx x_{ji,k} \approx 0$. Under these assumptions, we can use the WIOD data on good-specific expenditure, $\tilde{p}_{ij,k}q_{ij,k}$, to compute all the other variables needed to calibrate our theory to data. First, we can construct the within-industry expenditure shares as

$$\lambda_{ij,k} = \frac{\tilde{p}_{ij,k}q_{ij,k}}{\sum_n \tilde{p}_{in,k}q_{in,k}}.$$

Country i's total income which equals total wage income (without trade tax revenues) can be calculated as:

$$Y_i = w_i L_i = \sum_j \sum_k \left(\tilde{p}_{ji,k}q_{ji,k}\right).$$

The industry-level consumption shares are, accordingly, given by

$$e_{i,k} = \sum_j \left(\tilde{p}_{ji,k}q_{ji,k}\right) / Y_i.$$

Finally, to calibrate our theory to data, we need information on industry-level trade elasticities, ϵ_k. So, we complement the WIOD with industry-level trade elasticity estimates from Caliendo and Parro (2015), which are reported in 3.

6.3 Quantitative Results

Below, we present the results of our quantitative analysis. In summary, they confirm that the policy interdependencies outlined under Proposition 2-4 are quantitatively significant.

The Degree of Policy Interdependencies. We illustrate the degree of policy interdependence with the same thought experiment used in Section 5. We first start from the unconstrained optimal policy equilibrium. Then, we sequentially introduce a set of restrictions on the Home government's policy space:

i. In the first sequence, export taxes are restricted in *all* industries but import taxes are left to the discretion of the Home government.

ii. In the second sequence, export taxes remain restricted in all industries and import taxes are also restricted in *half* of the industries.

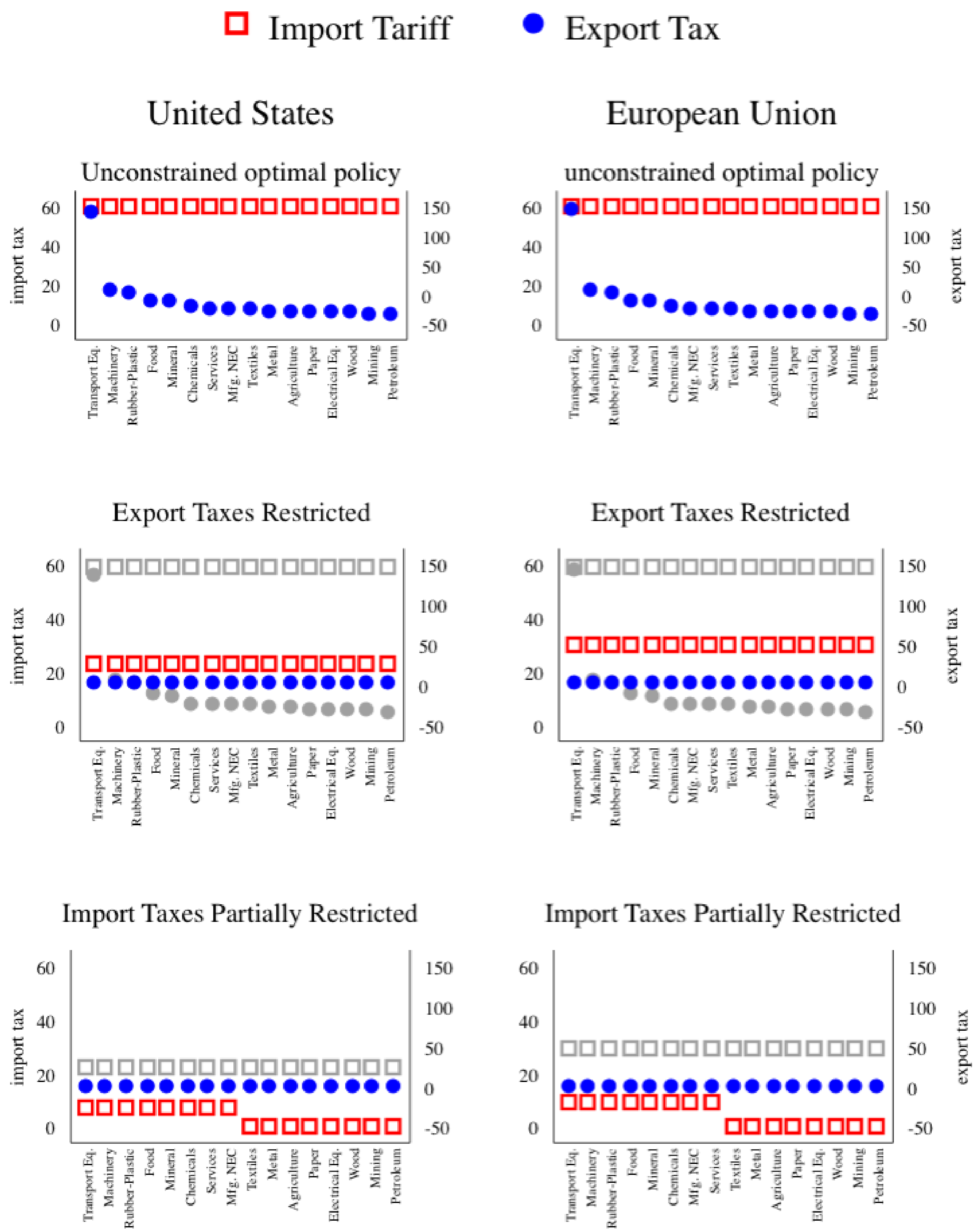
In each of these cases, we use the quantitative approach discussed earlier to compute the Home government's optimal tax schedule. We perform this exercise for every country in our sample as the Home country.[25] The results for the U.S. and E.U. are displayed in Figure 1. The top panel shows that the unconstrained optimal policy involves a uniform import tariff and differential export taxes/subsidies that vary across products.[26] The cross-product variation in the export policy is mainly driven by the variation in trade elasticities. The middle panel is related to the case where export policy is unavailable, in which case it is optimal for both the US and EU to voluntary lower their import taxes in all industries. More importantly, as we discuss later, this adjustment lowers the effective rate of protection.

The bottom panel in Figure 1 corresponds to the case where import taxes are also restricted in half of the industries in our sample. Specifically, setting tariffs exogenously equal to zero in industries with the highest trade elasticity, the optimal tariff in *unrestricted* industries decline from around 30% to 10%. These *tariff*

[25] EU is considered as one country.

[26] Recall that we deal with indeterminacy of optimal policies, by setting $\bar{t} = 0.59$.

Figure 1: *The interdependence of polices without input-output linkages*



complementarity effects are driven solely by a reduction in the *wage-driven* term, τ. Cross-substitutability between industries, which are absent here due to the Cobb-Douglas assumption, would magnify the degree of tariff complementarity. Our quantitative exercise, therefore, presents a lower bound on the degree of tariff complementarity.

The Welfare Gains from Partial Trade Liberalization. The gains from the sequential trade liberalization are reported in Table 1. Each row in this table concerns an exercise where one country is treated as Home, i.e., the country with active trade policy.

The second column in Table 1 reports the welfare loss for the rest of the world from the Home country's unilateral trade policy, namely, $\Delta W_f = W_f(\hat{W}_f - 1)$. The results here indicate that if the US and EU adopted their unilaterally optimal policy, real GDP in the rest of the would shrink by \$51 billion and \$28 billion, respectively. The optimal policy of smaller countries, like Turkey or Taiwan, imposes a lower ToT externality on the rest of the world. But the size of the ToT externality also depends on the tax-imposing country's export composition. For instance Russia's optimal policy inflicts a relatively small ToT externality because it exports primarily in low-market-power (low-ϵ) industries.

The third column in Table 1 reports the percentage drop in the ToT externality of Home's policy if export taxes/subsidies are banned. On average, a ban on export policy will lower the ToT externality of Home's trade policy by 62%. That is, if the Home country were forced to use only import tariffs, its optimal policy choice will be 62% less costly for the rest of the world compared to the case where export policy instruments are available.

The fourth column in Table 1 reports the percentage drop in the ToT externality

Table 1: The effect of banning a subset of trade policy measures

Country	ToT externality of Optimal Policy (*million dollars*)	% Reduction in the ToT Externality		
		ban on x_k	ban on x_k plus partial ban on t_k	ban on t_k and x_k
EU	\$51,360	52%	94%	98%
USA	\$27,659	62%	96%	99%
CHN	\$19,607	46%	96%	98%
JPN	\$18,653	57%	97%	98%
KOR	\$11,430	70%	98%	98%
CAN	\$7,663	76%	96%	98%
MEX	\$6,867	79%	98%	97%
BRA	\$3,544	59%	95%	94%
IND	\$3,385	58%	94%	99%
TUR	\$2,546	68%	97%	99%
TWN	\$2,463	66%	94%	94%
RUS	\$1,820	62%	92%	96%
IDN	\$1,626	60%	94%	100%
AUS	\$1,497	57%	90%	93%
Average	\$11,829	62%	95%	97%

Note: This table reports the terms of trade (ToT) externality of each country's trade policy on the rest of the world. The name of the Home country is listed in the first column. The second column reports the ToT externality of the unconstrained optimal policy on the ROW. The remaining columns report the reduction in the ToT externality at each stage of gradual liberalization. The partial ban on import taxes (t_k) applies to half of the industries with the lowest trade elasticity measures. The industry-level trade elasticities are taken from Caliendo and Parro (2015), as reported in Table 3 of the appendix.

of Home's policy if, in addition to export taxes, import tariffs are also banned in half of the industries with the highest trade elasticities. On average, the partial ban on import tariffs will lower the ToT externality of Home's trade policy by an additional 33%. So, the combination of a ban on export taxes and a partial ban on import tariffs liberalizes trade by a striking 95%. The intuition is that a partial ban on import tariffs will prompt the Home government to voluntarily lower its applied tariff in unrestricted industries (see the bottom row in Figure 1).

The last column in Table 1 reports the percentage drop in the ToT externality of Home's trade policy if all revenue-raising tax instruments were banned. Following Proposition 4, the Home government will erect NRTBs in this case, using them as a second-best instrument to mimic import tariffs. On average, the ToT externality of these NRTBs is 97% smaller than that of the unconstrained optimal policy schedule. This number is strikingly close to the 95% reduction in ToT externality that will occur if import tariffs where partially banned. In other words, if all export taxes are fully banned and import tariffs are also banned in half of the industries, negotiating tariff cuts in the remaining industries will not deliver much liberalization.

7 Concluding Remarks

In conclusion, we point out a few potential ways in which our characterization of constrained-optimal policy and policy interdependence can be used to enhance analyses of trade policies and agreements.

First, our general-equilibrium analysis of policies across multiple industries could guide future empirical studies of trade policy. In standard empirical works on trade policy, researchers usually use *comparative static results* from a partial-equilibrium model to explain cross-industry variation in policies. Interpreting comparative static results as cross-industry variation is less than satisfactory because it ignores cross-industry linkages, which are quantitatively important in the data. Our theory, by comparison, directly characterizes the cross-industry variation in optimal trade policies, which could be used as a guide for future empirical work in this area.

Second, our work provides a framework to re-evaluate, under a general-equilibrium framework, the standard results in the trade policy literature, including the previous analyses of the GATT/WTO rules and institutions, such as the

Principle of Reciprocity, the Most-Favored Nation clause, and the WTO's Dispute Settlement Process (Bagwell and Staiger, 1999, 2002; Beshkar, 2010; Maggi and Staiger, 2015). Most of these works either provide a partial-equilibrium analysis or assume a single import good and a single export good in general equilibrium.

For example, within a two-good, general-equilibrium framework, Bagwell and Staiger (1999) characterize useful properties of the principle of reciprocity, which regulates the exchange of concessions among the GATT/WTO members. According to this principle, if a member decides to increase its tariffs above the negotiated levels, the affected exporting countries have the right to respond by raising their own tariffs reciprocally. A quantitative definition of reciprocity, as suggested by Bagwell and Staiger (1999), is a mutual change in tariff rates that leads to an equal reduction of import volumes at original (i.e., pre-tariff hike) prices. Based on this definition, they show that under the Reciprocity Principle, efficiently-negotiated tariffs are impervious to renegotiations. Some of the other papers cited immediately above provide similar results under a partial-equilibrium framework. Nevertheless, under a multi-product general-equilibrium framework, which arguably represents the real world more accurately, the calculus of the reciprocity principle remains unknown. In particular, given the interdependence of tariffs across products, any concessions that are exchanged on certain tariff lines will affect each government's costs and benefits of protection in other industries. The constrained-optimum formulation that we provide in this paper could shed light on the full effect of the reciprocity principle.

Finally, in light of the tariff complementarity result that was expressed in Proposition 3, one could evaluate the optimality of an incomplete trade agreement. In particular, if free trade negotiations are costly and these costs are increasing in the number of tariff lines included in negotiations, an incomplete trade agreement may be optimal. To see this, note that as more products are imported tax-free, the government would voluntarily reduce its tariffs on other products, which reduces the value of further negotiations. Therefore, if negotiation costs are sufficiently high, the governments would find it optimal to negotiate liberalization on only a subset of products. Several important issues may be addressed within such a model of costly contracting, including the optimal sequence of tariff cuts across industries.

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Appendix

A Deriving F.O.C.s for the Optimal Policy Problem

The optimal trade tax problem of the home country can be formulated as

$$\max_{(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\tau};\boldsymbol{w})\in\mathbb{A}} \quad W_h\left(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\tau};\boldsymbol{w}\right),$$

where the set of feasible wage-policy combinations, $\mathbb{A}$, is defined such that for any vector of taxes, $\boldsymbol{t}$, $\boldsymbol{x}$, and $\boldsymbol{\tau}$, the vector of wages, $\boldsymbol{w}$, solves the balanced trade condition:[27]

$$D_h\left(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\tau};\boldsymbol{w}\right) \equiv \sum_g \left[\left(1+x_g\right) p_{hf,g}q_{hf,g} - p_{fh,g}q_{fh,g}\right] = 0$$

Note that in the presence of revenue-raising taxes, the optimal NRTB is zero. So, we henceforth drop $\boldsymbol{\tau}$ when referencing a feasible wage-policy combination in our proof. That is, we express all equilibrium outcomes in terms of a revenue-raising wage-policy combination, $(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w})$, with Foreign labor assigned as the numeraire (i.e., $w_f = 1$).

Deriving the F.O.C. with respect to t_k. We can express the F.O.C. with respect to the tariff in sector k, namely, t_k, as follows

$$\frac{\mathrm{d}W_h\left(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w}\right)}{\mathrm{d}\left(1+t_k\right)} = \frac{\partial V_h\left(Y_h,\tilde{\boldsymbol{p}}_h\right)}{\partial Y_h}\left[\frac{\partial Y_h}{\partial\left(1+t_k\right)} + \frac{\partial Y_h}{\partial w_h}\frac{\mathrm{d}w_h}{\mathrm{d}\left(1+t_k\right)}\right] + \\ \sum_g\sum_{j=f,h}\left(\frac{\partial V_h\left(Y_h,\tilde{\boldsymbol{p}}_h\right)}{\partial\tilde{p}_{jh,g}}\left[\frac{\partial\tilde{p}_{jh,g}}{\partial\left(1+t_k\right)} + \frac{\partial\tilde{p}_{jh,g}}{\partial w_h}\frac{\mathrm{d}w_h}{\mathrm{d}\left(1+t_k\right)}\right]\right) = 0,$$

[27] To be clear, in the balanced trade condition, $q_{fh,k}$ depends on Y_h in addition to $(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\tau};\boldsymbol{w})$. But Y_h can itself can be expressed as a function of $(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\tau};\boldsymbol{w})$, using the fact that $Y_h = w_hL_h + \sum_k\left(x_kp_{hf,k}q_{hf,k} + t_kp_{fh,k}q_{fh,k}\right)$.

Noting (i) the zero cross-passthrough of taxes onto consumer prices, i.e., $\partial \tilde{p}_{ji,g}/\partial\left(1+t_k\right) = 0$, if $ji,g \neq fh,k$, and (ii) the complete passthrough of taxes onto own prices, i.e., $\partial \tilde{p}_{fh,k}/\partial\left(1+t_k\right) = 1$; we can simplify the above condition as

$$\frac{\mathrm{d}W_h\left(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w}\right)}{\mathrm{d}\left(1+t_k\right)} = \frac{\partial V_h}{\partial Y_h}\left\{\frac{\partial Y_h}{\partial\left(1+t_k\right)} + \frac{\partial V_h/\partial \tilde{p}_{fh,k}}{\partial V_h/\partial Y_h}\frac{\partial \tilde{p}_{fh,k}}{\partial\left(1+t_k\right)} + \frac{\frac{\partial V_h}{\partial w_h}}{\frac{\partial V_h}{\partial Y_h}}\frac{\mathrm{d}w_h}{\mathrm{d}\left(1+t_k\right)}\right\} = 0$$

where $\frac{\partial V_h}{\partial w_h} = \frac{\partial Y_h}{\partial w_h}\frac{\partial V_h}{\partial Y_h} + \sum_g \sum_{j=h,f} \frac{\partial V_h}{\partial \tilde{p}_{jh,g}}\frac{\partial \tilde{p}_{jh,g}}{\partial w_h}$. In the above equation, $\frac{\partial Y_h}{\partial(1+t_k)}$ can be expressed as:

$$\begin{aligned}\frac{\partial Y_h\left(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w}\right)}{\partial\left(1+t_k\right)} &= \frac{\partial}{\partial\left(1+t_k\right)}\left\{w_i L_i + \sum_g\left[t_g p_{fh,g} q_{fh,g} + x_g p_{hf,g} q_{hf,g}\right]\right\} \\ &= p_{fh,k} q_{fh,k} + \sum_g\left(t_g p_{fh,g}\frac{\partial q_{fh,g}}{\partial \tilde{p}_{fh,k}}\right)\frac{\partial \tilde{p}_{fh,k}}{\partial\left(1+t_k\right)} + \sum_g\left(t_g p_{fh,g}\frac{\partial q_{fh,g}}{\partial Y_h}\right)\frac{\partial Y_h}{\partial\left(1+t_k\right)}.\end{aligned} \tag{15}$$

Note that due to the Lerner symmetry we can set $dw_h/d\left(1+t_k\right)$ to zero to identify one of the multiple optimal policy combinations. However, to thoroughly demonstrate this point and to also be in sync with subsequent proofs, we formally derive and substitute this term. To this end, we apply the implicit function theorem to the balance trade condition, $D_h\left(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w}\right) \equiv \sum_g\left[\left(1+x_g\right)p_{hf,g}q_{hf,g} - p_{fh,g}q_{fh,g}\right] = 0$, which yields the following:

$$\frac{\mathrm{d}w_h}{\mathrm{d}\left(1+t_k\right)} = \frac{-\partial D_h\left(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w}\right)/\partial\ln\left(1+t_k\right)}{\partial D_h\left(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w}\right)/\partial w_h} = \frac{-\sum_g\left[p_{fh,g}\frac{\partial q_{fh,g}}{\partial \tilde{p}_{fh,k}}\frac{\partial \tilde{p}_{fh,k}}{\partial(1+t_k)} + p_{fh,g}\frac{\partial q_{fh,g}}{\partial Y_h}\frac{\partial Y_h}{\partial(1+t_k)}\right]}{\partial D_h\left(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w}\right)/\partial w_h}.$$

Plugging the expressions for $\frac{\partial Y_h}{\partial(1+t_k)}$ and $\frac{\mathrm{d}w_h}{\mathrm{d}(1+t_k)}$ back into the the F.O.C. implies the following optimality condition:

$$\frac{\mathrm{d}W_h\left(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w}\right)}{\mathrm{d}\left(1+t_k\right)} = \frac{\partial V_h}{\partial Y_h}\left\{t_k p_{fh,k}\frac{\partial q_{fh,k}}{\partial \tilde{p}_{fh,k}}\frac{\partial \tilde{p}_{fh,k}}{\partial\left(1+t_k\right)} + p_{fh,k}q_{fh,k} + \sum_{g\neq k}\left(t_g p_{fh,g}\frac{\partial q_{fh,g}}{\partial \tilde{p}_{fh,k}}\right)\frac{\partial \tilde{p}_{fh,k}}{\partial\left(1+t_k\right)}\right.$$
$$+\sum_g\left(t_g p_{fh,g}\frac{\partial q_{fh,g}}{\partial Y_h}\right)\frac{\partial Y_h}{\partial\left(1+t_k\right)} + \frac{\partial V_h/\partial \tilde{p}_{fh,k}}{\partial V_h/\partial Y_h}\frac{\partial \tilde{p}_{fh,k}}{\partial\left(1+t_k\right)}$$
$$\left.-\frac{\frac{\partial V_h}{\partial w}/\frac{\partial V_h}{\partial Y_h}}{\frac{\partial D_h}{\partial w}}\left[\sum_g\left(p_{fh,g}\frac{\partial q_{fh,g}}{\partial \tilde{p}_{fh,k}}\right)\frac{\partial \tilde{p}_{fh,k}}{\partial\left(1+t_k\right)} + \sum_g\left(p_{fh,g}\frac{\partial q_{fh,g}}{\partial Y_h}\right)\frac{\partial Y_h}{\partial\left(1+t_k\right)}\right]\right\} = 0$$

Applying Roy's identity, $\left(\partial V_h/\partial \tilde{p}_{fh,k}\right)/\left(\partial V_h/\partial Y_h\right) = -q_{fh,k}$; defining $\bar{\tau} \equiv \left(\frac{\partial V_h}{\partial w}/\frac{\partial V_h}{\partial Y_h}\right)/\frac{\partial D_h}{\partial w}>0$; and noting that $\partial \ln \tilde{p}_{fh,k}/\partial \ln\left(1+t_k\right) = 1$, we can further simplify the F.O.C. as

$$\sum_g\left[\left(\bar{\tau}-t_g\right)p_{fh,g}q_{fh,g}\left(\frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\frac{\partial \ln Y_h}{\partial \ln\left(1+t_k\right)} + \frac{\partial \ln q_{fh,g}}{\partial \ln \tilde{p}_{fh,k}}\right)\right] = 0,$$

Recalling our Definition D1 that (i) $\varepsilon_{fh,k} \equiv \partial \ln q_{fh,k}/\partial \ln \tilde{p}_{fh,k}$, (ii) $\varepsilon_{fh,k}^{fh,g} \equiv \partial \ln q_{fh,k}/\partial \ln \tilde{p}_{fh,g}$, and (iii) $\eta_{fh,k} \equiv \partial \ln q_{fh,k}/\partial \ln Y_h$, we can further simplify the F.O.C. as a function of reduced-form elasticities,

$$\sum_g\left[\left(1-\frac{1+\bar{\tau}}{1+t_g}\right)\left(\varepsilon_{fh,g}^{fh,k} + \eta_{fh,g}\frac{\partial \ln Y_h}{\partial \ln\left(1+t_k\right)}\right)\acute{\lambda}_{fh,g}\right] = 0, \text{ for all } k. \tag{16}$$

Deriving the F.O.C. with respect to x_k. Noting our notation for consumer prices that $\tilde{p}_{hf,k} = \left(1+x_k\right)p_{hf,k}$, the F.O.C. with respect to the export tax in sector k can be expressed as follows

$$\frac{\mathrm{d}W_h\left(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w}\right)}{\mathrm{d}\left(1+x_k\right)} = \frac{\partial V_h}{\partial Y_h}\left[\frac{\partial Y_h}{\partial\left(1+x_k\right)} + \frac{\partial Y_h}{\partial w_h}\frac{\mathrm{d}w_h}{\mathrm{d}\left(1+x_k\right)}\right]$$
$$+\sum_g\sum_{j=f,h}\left[\frac{\partial V_h}{\partial \tilde{p}_{jh,g}}\frac{\partial \tilde{p}_{jh,g}}{\partial\left(1+x_k\right)} + \frac{\partial V_h}{\partial \tilde{p}_{jh,g}}\frac{\partial \tilde{p}_{jh,g}}{\partial w_h}\frac{\mathrm{d}w_h}{\mathrm{d}\left(1+x_k\right)}\right] = 0$$

in the above expression, (i) $\frac{\partial \tilde{p}_{jh,g}}{\partial 1+x_k} = 0$ for all g because the effect of export taxes on Home prices are only through their effects on wages, and (ii) $\frac{\partial \tilde{p}_{fh,g}}{\partial w_h} = 0$ for all g, by normalization of foreign wage to 1. Plugging these values in to the above equation, yields the following simplified F.O.C.,

$$\frac{\mathrm{d}W_h(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w})}{\mathrm{d}\ln(1+x_k)} = \frac{\partial V_h}{\partial Y_h}\left\{\frac{\partial Y_h}{\partial \ln(1+x_k)} + \left(\frac{\partial V_h}{\partial w_h}/\frac{\partial V_h}{\partial Y_h}\right)\frac{\mathrm{d}w_h}{\mathrm{d}\ln(1+x_k)}\right\} = 0 \tag{17}$$

where, as before, $\frac{\partial V_h}{\partial w_h} = \frac{\partial Y_h}{\partial w_h}\frac{\partial V_h}{\partial Y_h} + \sum_g \sum_{j=h,f} \frac{\partial V_h}{\partial \tilde{p}_{jh,g}}\frac{\partial \tilde{p}_{jh,g}}{\partial w_h}$. The term $\partial Y_h/\partial \ln 1 + x_k$ in Equation 17 can be calculated as,

$$\begin{aligned}\frac{\partial Y_h(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w})}{\partial \ln(1+x_k)} &= \frac{\partial}{\partial(1+x_k)}\left\{w_i L_i + \sum_g \left(t_g p_{fh,g} q_{fh,g} + x_g p_{hf,g} q_{hf,g}\right)\right\} \\ &= \tilde{p}_{hf,k} q_{hf,k} + \sum_g \left(x_g p_{hf,g} q_{hf,g} \frac{\partial \ln q_{hf,g}}{\partial \ln \tilde{p}_{hf,k}}\right)\frac{\partial \ln \tilde{p}_{hf,k}}{\partial \ln(1+x_k)} + \\ &\quad \sum_g \left(t_g p_{fh,g} q_{fh,g}\frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\right)\frac{\partial \ln Y_h}{\partial \ln(1+x_k)}.\end{aligned} \tag{18}$$

Also, as with the case of import taxes, an expression for $dw_h/d\ln 1 + x_k$ can be derived by applying the implicit function theorem to the balance trade condition:

$$\begin{aligned}\frac{\mathrm{d}w_h}{\mathrm{d}\ln(1+x_k)} &= \frac{\partial D_h(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w})/\partial \ln(1+x_k)}{\partial D_h(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w})/\partial w_h} = \frac{\partial\left(\sum_g p_{fh,g} q_{fh,g} - \tilde{p}_{hf,g} q_{hf,g}\right)/\partial \ln(1+x_k)}{\partial D_h(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w})/\partial w_h} \\ &= \frac{\sum_g \left(p_{fh,g} q_{fh,g}\frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\right)\frac{\partial \ln Y_h}{\partial \ln(1+x_k)} - \tilde{p}_{hf,k} q_{hf,k} - \sum_g \left(\tilde{p}_{hf,g} q_{hf,g}\frac{\partial \ln q_{hf,g}}{\partial \ln \tilde{p}_{hf,k}}\right)\frac{\partial \ln \tilde{p}_{hf,k}}{\partial \ln(1+x_k)}}{\partial D_h(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w})/\partial w_h}.\end{aligned}$$

Replacing the expressions for $dw_h/d\ln(1+x_k)$ and $\partial Y_h/\partial \ln(1+x_k)$ into Equation 17; defining $\bar{\tau} \equiv \left(\frac{\partial V_h}{\partial w}/\frac{\partial V_h}{\partial Y_h}\right)/\frac{\partial D_h}{\partial w}$, as before; and Noting that $\partial \ln \tilde{p}_{hf,k}/\partial \ln(1+x_k) = 1$, the

F.O.C. reduces to

$$\frac{\mathrm{d}W_h(\boldsymbol{t},\boldsymbol{x};\boldsymbol{w})}{\mathrm{d}\ln(1+x_k)} = \frac{\partial V_h}{\partial Y_h}\left\{\tilde{p}_{hf,k}q_{hf,k} + \sum_g\left(x_g p_{hf,g}q_{hf,g}\frac{\partial \ln q_{hf,g}}{\partial \ln \tilde{p}_{hf,k}}\right) + \sum_g\left(t_g p_{fh,g}q_{fh,g}\frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\right)\frac{\partial \ln Y_h}{\partial \ln(1+x_k)} - \right.$$

$$\left.\bar{\tau}\left(\sum_g\left(p_{fh,g}q_{fh,g}\frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\right)\frac{\partial \ln Y_h}{\partial \ln(1+x_k)} - \tilde{p}_{hf,k}q_{hf,k} - \sum_g\left(\tilde{p}_{hf,g}q_{hf,g}\frac{\partial \ln q_{hf,g}}{\partial \ln \tilde{p}_{hf,k}}\right)\right)\right\} =$$

$$\frac{\partial V_h}{\partial Y_h}\left\{(1+x_k)(1+\bar{\tau}) + \sum_g\left(\left[(1+x_g)(1+\bar{\tau})-1\right]\frac{p_{hf,g}q_{hf,g}}{p_{hf,k}q_{hf,k}}\frac{\partial \ln q_{hf,g}}{\partial \ln \tilde{p}_{hf,k}}\right) - \right.$$

$$\left.\sum_g\left(\left[t_g-\bar{\tau}\right]\frac{p_{fh,g}q_{fh,g}}{p_{hf,k}q_{hf,k}}\frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\right)\frac{\partial \ln Y_h}{\partial \ln(1+x_k)}\right\}p_{hf,k}q_{hf,k} = 0.$$

Rearranging and simplifying the above equation, the F.O.C. w.r.t. x_k reduces to:

$$\tilde{p}_{hf,k}q_{hf,k} + \sum_g\left(\left[1-\frac{1}{(1+x_g)(1+\bar{\tau})}\right]\tilde{p}_{hf,g}q_{hf,g}\frac{\partial \ln q_{hf,g}}{\partial \ln \tilde{p}_{hf,g}}\right)$$
$$+\sum_g\left(\left[t_g-\bar{\tau}\right]p_{fh,g}q_{fh,g}\frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\right)\frac{\partial \ln Y_h}{\partial \ln(1+x_k)} = 0$$

Recalling Definition D1 that (i) $\varepsilon_{hf,k} \equiv \partial \ln q_{hf,k}/\partial \ln \tilde{p}_{hf,k}$, (ii) $\varepsilon^{hf,k}_{hf,g} \equiv \partial \ln q_{hf,g}/\partial \ln \tilde{p}_{hf,k}$, and noting that (iii) $\frac{p_{hf,g}q_{hf,g}}{p_{hf,k}q_{hf,k}} = \frac{1+x_k}{1+x_g}\frac{\lambda_{hf,g}}{\lambda_{hf,k}}$, the above condition can be written in terms of trade shares and reduced-form elasticities as follows:

$$\acute{\lambda}_{hf,k} + \sum_g\left(\left[1-\frac{1}{(1+x_g)(1+\bar{\tau})}\right]\acute{\lambda}_{hf,g}\varepsilon^{hf,k}_{hf,g}\right) \tag{19}$$

$$+\sum_g\left(\left[t_g-\bar{\tau}\right]\acute{r}_{fh,g}\eta_{fh,g}\right)\frac{\partial \ln Y_h}{\partial \ln(1+x_k)} = 0. \tag{20}$$

A.1 Unconstrained Optimal Tax Schedule

To determine the unconstrained optimal trade tax schedule, we need to jointly solve the system of F.O.C.s specified by Equations 16 and 19. We can simplify this task by appealing to the following observation: For any vector of export taxes, the trivial solution to the system of first-order conditions specified by Equation 16 is $t_k = \bar{\tau}$ for all k. We can also characterize conditions that ensure that the trivial solution, $t_k = \bar{\tau}_k$, is the unique solution. To this end, define the $K \times K$ matrix $\boldsymbol{B}$ as

$$\boldsymbol{B} \equiv \left[\acute{\lambda}_{fh,g} \left(\varepsilon_{fh,g}^{fh,k} + \eta_{fh,g} \frac{\partial \ln Y_h}{\partial \ln (1+t_k)} \right) \right]_{k,g},$$

and the $K \times 1$ vector $\boldsymbol{\omega}$ as $\boldsymbol{\omega} \equiv \left[1 - \frac{1+\bar{\tau}}{1+t_k} \right]_k$. The system of F.O.C.s can, thus, be expressed as $\boldsymbol{B}\boldsymbol{\omega} = \boldsymbol{0}$. For $\boldsymbol{\omega} = \boldsymbol{0}$ to be the unique (and trivial) solution to $\boldsymbol{B}\boldsymbol{\omega} = \boldsymbol{0}$, it suffices that $\det \boldsymbol{B} \neq 0$.

We can also check that the *second-order condition* for optimality is also satisfied at $t_k = \bar{\tau}$. Specifically, given that $\varepsilon_{fh,k} < 0$, $\varepsilon_{fh,k}^{fh,g} > 0$, and $\eta_{fh,g} > 0$, we can easily verify that (i) if $t_k < \bar{\tau} \mid t_g = \bar{\tau}$, $\forall g \neq k$ then,

$$\frac{\partial W_h (\boldsymbol{t}, \boldsymbol{x}; \boldsymbol{w})}{\partial (1+t_k)} = \sum_g \left((t_g - \bar{\tau}) \, p_{fh,g} q_{fh,g} \left[\varepsilon_{fh,g}^{fh,k} + \frac{\partial \ln Y_h}{\partial \ln (1+t_k)} \eta_{fh,g} \right] \right) > 0$$

and (ii) if $t_k > \bar{\tau} \mid t_g = \bar{\tau}$, $\forall g \neq k$ then

$$\frac{\partial W_h (\boldsymbol{t}, \boldsymbol{x}; \boldsymbol{w})}{\partial (1+t_k)} = \sum_g \left((t_g - \bar{\tau}) \, p_{fh,g} q_{fh,g} \left[\varepsilon_{fh,g}^{fh,k} + \frac{\partial \ln Y_h}{\partial \ln (1+t_k)} \eta_{fh,g} \right] \right) < 0.$$

Hence, the solution $t_k = \bar{\tau}$ for all k, is also a *welfare-maximizing* solution to the F.O.C.

To determine the vector of optimal export taxes, we need to plug $t_k = \bar{\tau}$ into the system of F.O.C.s specified by Equation 19, which yields:

$$\acute{\lambda}_{hf,k} + \sum_g \left(\left[1 - \frac{1}{(1+x_g)(1+\bar{\tau})} \right] \acute{\lambda}_{hf,g} \varepsilon_{hf,g}^{hf,k} \right).$$

To attain a simplified expression for x_k^*, define

$$\xi_{hf,k} \equiv \sum_{g \neq k} \left[1 - \frac{1}{(1+x_g)(1+\bar{\tau})} \right] \frac{\acute{\lambda}_{hf,g}}{\acute{\lambda}_{hf,k}} \varepsilon_{hf,g}^{hf,k},$$

Appealing to the above definition, Equation 19 yields the following formula for the optimal import and export taxes

$$(1 + x_k^*)\,(1 + \bar{\tau}) = \frac{\varepsilon_{hf,k}}{1 + \varepsilon_{hf,k} + \xi_{hf,k}}. \tag{21}$$

The term $\xi_{hf,k}$ accounts for cross-price elasticity effects. To see this, note that if cross-price elasticities are zero (i.e., $\varepsilon_{hf,g}^{hf,k} = 0$ for all $g \neq k$), then $\xi_{hf,k} = 0$. In order to calculate $\xi_{hf,k}$ based on cross-price elasticities, we can rewrite the equation expressing $\xi_{hf,k}$ as follows:

$$\xi_{hf,k} = -\sum_{g \neq k} \left[\xi_{hf,g} + 1\right] \frac{\acute{\lambda}_{hf,g}}{\acute{\lambda}_{hf,k}} \frac{\varepsilon_{hf,g}^{hf,k}}{\varepsilon_{hf,k}}.$$

The vector $\left[\xi_{hf,k}\right]_k$, therefore, solves $\sum_g \left(\xi_{hf,k} + 1\right) \acute{\lambda}_{hf,g}\varepsilon_{hf,g}^{hf,k} / \acute{\lambda}_{hf,k}\varepsilon_{hf,k} = 1$; namely,

$$\left[\xi_{hf,k}\right]_{k,1} = \left[\boldsymbol{\Xi}^{-1} - \boldsymbol{I}_K\right] \mathbf{1}_K,$$

where $\boldsymbol{\Xi} \equiv \left[\acute{\lambda}_{hf,g}\varepsilon_{hf,g}^{hf,k} / \acute{\lambda}_{hf,k}\varepsilon_{hf,k}\right]_{k,g}$ is a $K \times K$ matrix and $\mathbf{1} \equiv [1]_k$ is a $K \times 1$ vector. Since $\sum_g \acute{\lambda}_{hf,g}\varepsilon_{hf,g}^{hf,k} = -\acute{\lambda}_{hf,k} - \sum_g \acute{\lambda}_{ff,g}\varepsilon_{ff,g}^{hf,k} < 0$, then $\boldsymbol{\Xi}$ is strictly diagonally dominant. Therefore, $\boldsymbol{\Xi}^{-1}$ exists and is monotone, which ensures that $\xi_{hf,k} + 1 > 0$ (Berman and Plemmons (1994)). That is to say, with zero import tariffs an export subsidy is never optimal. Finally, note that (by the Lerner symmetry) the exact value of $\bar{\tau}$ is irrelevant. Specifically, we can assign any non-negative value to $1 + \bar{\tau}$ and identify one of the many optimal trade tax schedules..

A.2 The Case with a Continuum of Goods

This appendix demonstrates that our theory extends to an environment with a continuum of homogeneous goods à la Dornbusch et al. (1977) (DFS, hereafter). To this end, note that first-order conditions and the optimal tax formulas derived earlier continue to hold if we sum of over a continuum (rather than a discrete) set of goods. That is because, our previous derivation imposed no parametric restrictions on consumer preferences. Moreover, in the DFS model, that cross-price elasticities are zero since the expenditure share on each good is infinitesimally small. Considering this, the optimal trade tax schedule in the DFS model is given by

$$\left(1+x_k^*\right)\left(1+\bar{t}\right)=\frac{\varepsilon_{hf,k}}{1+\varepsilon_{hf,k}}.$$

Assuming CES preferences with elasticity of substitution σ, the trade elasticity at an interior solution will be given by $\epsilon_{hf,k}=-\sigma$, and the optimal tariff, at an interior solution, will be given by $\frac{\sigma}{\sigma-1}$. An interior solution is obtained if and only if

$$1\geq\frac{a_{ff,k}w_f}{a_{hf,k}w_h}\geq\frac{\sigma}{\sigma-1},$$

that is, iff the mark-up that is induced by the tariff is not larger than the ratio of foreign to Home cost of producing goods k. At a corner solution, i.e., for $\frac{a_{ff,k}w_f}{a_{hf,k}w_h}<\frac{\sigma}{\sigma-1}$, the optimal markup takes a limit-pricing form, i.e., $x_k^*=\frac{a_{ff,k}w_f}{a_{hf,k}w_h}$. We can also establish this claim more formally, by deriving the optimal monopoly markup (in the limit) as industries become homogeneous. Namely, by showing that

$$1+x_k^*=\lim_{\epsilon_k\to\infty}\frac{\varepsilon_{hf,k}}{1+\varepsilon_{hf,k}}=\lim_{\epsilon_k\to\infty}1+\frac{1}{\epsilon_k\lambda_{ff,k}+\left(\sigma-1\right)\lambda_{ff,k}}. \tag{22}$$

To elaborate, our claim is that based on the above equation, if $1\geq\frac{a_{hf,k}w_h}{a_{ff,k}w_f}\geq\frac{\sigma-1}{\sigma}$, then

$$1+x_k^*=\frac{a_{ff,k}w_f}{a_{hf,k}w_h}.$$

Noting that $\lim_{\varkappa\to0}\varkappa\ln\frac{\mathsf{a}}{\varkappa}=0$, to establish the above claim, it suffices to show that $1+x_k^*=\frac{a_{ff,k}w_f}{a_{hf,k}w_h}\left[1-\frac{1}{\epsilon_k}\ln\mathsf{a}_k\epsilon_k\right]$ is a solution to Equation 22, when $\mathsf{a}_k\equiv\frac{\frac{a_{ff,k}w_f}{a_{hf,k}w_h}-1}{1-(\sigma-1)\frac{a_{ff,k}w_f}{a_{hf,k}w_h}}$. To establish this claim, notice that *conditional* trade shares in industry/good k are given by

$$\tilde{\lambda}_{ff,k} = \frac{\left(a_{ff,k} w_f\right)^{-\epsilon_k}}{\left(a_{ff,k} w_f\right)^{-\epsilon_k} + \left(\left[1 + x_k\right] a_{hf,k} w_h\right)^{-\epsilon_k}} = \frac{\left(\frac{(1+x_k) a_{hf,k} w}{a_{ff,k} w_f}\right)^{\epsilon_k}}{1 + \left(\frac{(1+x_k) a_{hf,k} w}{a_{ff,k} w_f}\right)^{\epsilon_k}}.$$

Plugging the above formula and our guess for the export tax, $1 + x_k^* = \frac{a_{ff,k} w_f}{a_{hf,k} w_h}\left[1 - \frac{1}{\epsilon_k} \ln \mathrm{a}_k \epsilon_k\right]$, into Equation 22 yields the following

$$\lim_{\epsilon_k \to \infty} 1 + \frac{1}{\left(\epsilon_k - \sigma + 1\right) \tilde{\lambda}_{ff,k} + \sigma - 1} = 1 + \lim_{\epsilon_k \to \infty} \frac{1}{\epsilon_k \left(\frac{(1+x_k) a_{hf,k} w}{a_{ff,k} w_f}\right)^{\epsilon_k} + \sigma - 1}$$

$$= 1 + \frac{1}{\lim_{\epsilon_k \to \infty} \epsilon_k \left[1 - \frac{1}{\epsilon_k} \ln \mathrm{a}_k \epsilon_k\right]^{\epsilon_k}} = 1 + \frac{1}{\frac{1}{\mathrm{a}_k} + (\sigma - 1)} = \frac{a_{ff,k} w_f}{a_{hf,k} w_h} = \lim_{\epsilon_k \to \infty} 1 + x_k^*,$$

where the second line uses the fact that $\lim_{\varkappa \to \infty} \varkappa \left(1 - \frac{\ln \mathrm{a}\varkappa}{\varkappa}\right)^{\varkappa} = \frac{1}{\mathrm{a}}$. That is, $1 + x_k^* = \lim_{\epsilon_k \to \infty} \frac{a_{ff,k} w_f}{a_{hf,k} w_h}\left[1 - \frac{1}{\epsilon_k} \ln \mathrm{a}_k \epsilon_k\right]$, is the solution implied by Equation 22. Correspondingly, if $\frac{a_{hf,k} w_h}{a_{ff,k} w_f} < \frac{\sigma - 1}{\sigma}$, then $1 + x_k^* = \frac{\sigma}{\sigma - 1}$ is the implied solution of Equation 22, given that $\lambda_{ff,k}(x_k^*) = 0$ and $\lambda_{hf,k}(x_k^*) = 1$.

B Proof of Propositions 1

This section employs the first-order conditions produced in Appendix A to derive the best tax-response formulas presented under Proposition 1.

Optimal Import Tax Response. Recall from Appendix A that the F.O.C. for the tariff in industry k is given by

$$\sum_g \left[\left(t_g - \bar{\tau}\right)\left(\varepsilon_{fh,g}^{fh,k} + \eta_{fh,g} \frac{\partial \ln Y_h}{\partial \ln\left(1 + t_k\right)}\right) p_{fh,k} q_{fh,k}\right] = 0, \text{ for all } k.$$

where $\bar{\tau} \equiv \left(\frac{\partial V_h}{\partial w_h} / \frac{\partial V_h}{\partial Y_h}\right) / \frac{\partial D_h}{\partial w_h}$. Applying the implicit function theorem to $Y_h = w_h L_h + \sum_g \left(t_g p_{fh,g} q_{fh,g} + x_g p_{hf,g} q_{hf,g}\right)$, we will have

$$Y_h \frac{\partial \ln Y_h}{\partial \ln (1+t_k)} = \frac{\tilde{p}_{fh,g} q_{fh,g} + \sum_g \left(t_g p_{fh,g} q_{fh,g} \frac{\partial \ln q_{fh,g}}{\partial \ln \tilde{p}_{fh,k}}\right) \frac{\partial \ln \tilde{p}_{fh,k}}{\partial \ln(1+t_k)}}{1 - \sum_g \left(t_g \frac{p_{fh,g} q_{fh,g}}{Y_h} \frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\right)}.$$

Plugging the above equation back into the F.O.C., and defining

$$\Upsilon \equiv \frac{1 - \sum_g \left(t_g \frac{p_{fh,g} q_{fh,g}}{Y_h} \frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\right)}{1 - \sum_g \left(\bar{\tau} \frac{p_{fh,g} q_{fh,g}}{Y_h} \frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\right)} = \frac{1 - \sum_g \left(\frac{t_g}{1+t_g} \lambda_{fh,g} \eta_{fh,g}\right)}{1 - \sum_g \left(\frac{\bar{\tau}}{1+t_g} \lambda_{fh,g} \eta_{fh,g}\right)},$$

allows us to further simplify the F.O.C. as

$$(1-\Upsilon)(1+t_k) p_{fh,k} q_{fh,k} + \sum_g \left[\left(t_g - \Upsilon \bar{\tau}\right) p_{fh,g} q_{fh,g} \varepsilon^{fh,k}_{fh,g}\right] = 0.$$

Rearranging the above expression implies the following formula for optimal tariff in industry k as a function of applied tariffs in other industries:

$$1 + t_k^* = (1 + \Upsilon \bar{\tau}) \left(1 + \frac{1-\Upsilon}{\varepsilon_{fh,k}}\right)^{-1} \left(1 + \sum_{g \neq k} \left[\left(\frac{1+t_g}{1+\Upsilon \bar{\tau}} - 1\right) \frac{\lambda_{fh,g} \varepsilon^{fh,k}_{fh,g}}{\lambda_{fh,k} \varepsilon_{fh,k}}\right]\right).$$

Note that when traded industries exhibit a zero income elasticity, which is the case in our analysis in Section 5, then $\Upsilon = 1$ and the above equation reduces to 9.

Optimal Export Tax Response. As shown in Appendix A, the F.O.C. w.r.t. the export tax in industry k can be stated as

$$\tilde{p}_{hf,k} q_{hf,k} + \sum_g \left(\left[1 - \frac{1}{(1+x_g)(1+\bar{\tau})}\right] \tilde{p}_{hf,g} q_{hf,g} \frac{\partial \ln q_{hf,g}}{\partial \ln \tilde{p}_{hf,g}}\right) + \sum_g \left(\left[t_g - \bar{\tau}\right] p_{fh,g} q_{fh,g} \frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\right) \frac{\partial \ln Y_h}{\partial \ln (1+x_k)} = 0.$$

Applying the Implicit Function Theorem to $Y_h = w_h L_h + \sum_g \left(t_g p_{fh,g} q_{fh,g} + x_g p_{hf,g} q_{hf,g}\right)$, the term $\frac{\partial \ln Y_h}{\partial \ln(1+x_k)}$ in the above equation can be expresses as

$$Y_h \frac{\partial \ln Y_h}{\partial \ln(1+x_k)} = \frac{\tilde{p}_{hf,g} q_{hf,g} + \sum_g \left(x_g p_{hf,g} q_{hf,g} \frac{\partial \ln q_{hf,g}}{\partial \ln \tilde{p}_{hf,k}}\right) \frac{\partial \ln \tilde{p}_{hf,k}}{\partial \ln(1+x_k)}}{1 - \sum_g \left(t_g \frac{p_{fh,g} q_{fh,g}}{Y_h} \frac{\partial \ln q_{fh,g}}{\partial \ln Y_h}\right)}.$$

Plugging the above expression back into the F.O.C. and defining Υ and $\bar{\tau}$ as before, implies the following optimality condition:

$$(1+x_k)(1+\Upsilon\bar{\tau})\left\{1+\varepsilon_{hf,k} + \sum_{g\neq k}\left(\left[1 - \frac{1}{(1+x_g)(1+\Upsilon\bar{\tau})}\right]\frac{\acute{\lambda}_{hf,g}}{\acute{\lambda}_{hf,k}}\varepsilon_{hf,g}^{hf,k}\right)\right\} = \varepsilon_{hf,k},$$

Rearranging the above equation implies the following formula for the optimal export tax in industry k as a function of applied taxes in other industries:

$$(1+x_k)(1+\Upsilon\bar{\tau}) = \frac{\varepsilon_{hf,k}}{1+\varepsilon_{hf,k} + \sum_{g\neq k}\left[1 - \frac{1}{(1+x_g)(1+\Upsilon\bar{\tau})}\right]\frac{\acute{\lambda}_{hf,g}}{\acute{\lambda}_{hf,k}}\varepsilon_{hf,g}^{hf,k}}.$$

Solving for $1+\bar{\tau}$. To finalize the characterization of the restricted optimal taxes, we also need to characterize $\bar{\tau} \equiv \left(\frac{\partial V_h}{\partial w_h} / \frac{\partial V_h}{\partial Y_h}\right) / \frac{\partial D_h}{\partial w_h}$. To this end, we can follow the same steps presented in Appendix A. That is, defining $X \equiv pq$, $\bar{\tau}$ can be expressed as

$$1+\bar{\tau} = 1+\frac{w_h L_h \frac{\partial \ln(w_h L_h)}{\partial \ln w_h} + \sum_k \left(t_k p_{fh,k} q_{fh,k} \frac{\partial \ln\left(p_{fh,k} q_{fh,k}\right)}{\partial \ln w_h} + x_k p_{hf,k} q_{hf,k} \frac{\partial \ln\left(p_{hf,k} q_{hf,k}\right)}{\partial \ln w_h} - \frac{\partial V_h / \partial \tilde{p}_{hh,k}}{\partial V_h / \partial Y_h} \tilde{p}_{hh,k} \frac{\partial \tilde{p}_{hh,k}}{\partial \ln w_h} \right)}{\sum_k \left(p_{fh,k} q_{fh,k}\right) \frac{\partial \ln \sum_k \left(p_{fh,k} q_{fh,k}\right)}{\partial \ln w_h} - \sum_k \left(\tilde{p}_{hf,k} q_{hf,k}\right) \frac{\partial \ln \sum_k \left(\tilde{p}_{hf,k} q_{hf,k}\right)}{\partial \ln w_h}}$$

$$= 1 + \frac{\sum_k \left(p_{hf,k} q_{hf,k}\right) + \sum_k \left(t_k p_{fh,k} q_{fh,k} \frac{\partial \ln\left(p_{fh,k} q_{fh,k}\right)}{\partial \ln w_h} + \left[\tilde{p}_{hf,k} - p_{hf,k}\right] q_{hf,k} \frac{\partial \ln\left(p_{hf,k} q_{hf,k}\right)}{\partial \ln w_h} \right)}{\sum_k \left(p_{fh,k} q_{fh,k}\right) \frac{\partial \ln \sum_k \left(p_{fh,k} q_{fh,k}\right)}{\partial \ln w_h} - \sum_k \left(\tilde{p}_{hf,k} q_{hf,k}\right) \frac{\partial \ln \sum_k \left(\tilde{p}_{hf,k} q_{hf,k}\right)}{\partial \ln w_h}}$$

$$= \frac{\sum_k \left[(1+t_k) \frac{\acute{r}_{fh,k}}{\acute{r}_{fh}} \frac{\partial \ln\left(p_{fh,k} q_{fh,k}\right)}{\partial \ln w_h} \right] - \frac{\sum_g \left(p_{hf,g} q_{hf,g}\right)}{\sum_g \left(\tilde{p}_{hf,g} q_{hf,g}\right)} \sum_k \left[\frac{\acute{r}_{fh,k}}{\acute{r}_{fh}} \left(\frac{\partial \ln\left(p_{hf,k} q_{hf,k}\right)}{\partial \ln w_h} - 1 \right) \right]}{\frac{\partial \ln \sum_k \left(p_{fh,k} q_{fh,k}\right)}{\partial \ln w_h} - \frac{\partial \ln \sum_k \left(\tilde{p}_{hf,k} q_{hf,k}\right)}{\partial \ln w_h}}$$

$$= \frac{\sum_k \left[(1+t_k) \frac{\acute{r}_{fh,k}}{\acute{r}_{fh}} \frac{\partial \ln \mathcal{L}_{fh,k}(\boldsymbol{w})}{\partial \ln w_h} \right] - (1+\bar{x})^{-1} \sum_k \left[\frac{\acute{r}_{fh,k}}{\acute{r}_{fh}} \frac{\partial \ln \mathcal{L}_{hf,k}(\boldsymbol{w})}{\partial \ln w_h} \right]}{\frac{\partial \ln \mathcal{L}_{fh}(\boldsymbol{w})}{\partial \ln w_h} - \frac{\partial \ln (1+\bar{x})^{-1} \mathcal{L}_{hf}(\boldsymbol{w})}{\partial \ln w_h}} = \frac{(1+\bar{t})\, \tilde{\varepsilon}_{fh} + (1+\bar{x})^{-1} \tilde{\varepsilon}_{hf}}{1 + \tilde{\varepsilon}_{hf} + \tilde{\varepsilon}_{fh}}.$$

where (i) $1+\bar{x} \equiv \frac{\sum_g \left(\tilde{p}_{hf,g} q_{hf,g}\right)}{\sum_g \left(p_{hf,g} q_{hf,g}\right)} = \sum_k \left[\frac{\acute{r}_{fh,k}}{\acute{r}_{fh}} (1+x_k) \right]$, (ii) $1+\bar{t} \equiv \sum_k \left[(1+t_k) \frac{\acute{r}_{fh,k}}{\acute{r}_{fh}} \frac{\tilde{\varepsilon}_{fh,k}}{\tilde{\varepsilon}_{fh}} \right]$, and (vi) $\tilde{\varepsilon}_{ji,k} \equiv \sum_g \varepsilon_{ji,k}^{ji,g}$ and $\tilde{\varepsilon}_{ji} \equiv \sum_g \frac{\acute{r}_{ji,g}}{\acute{r}_{ji}} \tilde{\varepsilon}_{ji,g}$ denote the elasticity of labor demand per D4.[28] Also, note that in deriving the above expression we use the fact that $\frac{\partial \ln\left(p_{hf,k} q_{hf,k}\right)}{\partial \ln w_h} = 1 + \frac{\partial \ln \mathcal{L}_{hf,k}(\boldsymbol{w})}{\partial \ln w_h}$, as well as the fact that (absent of income effects) $\frac{\partial \ln \mathcal{L}_{fh,k}(\boldsymbol{w})}{\partial \ln w_h} = -\frac{\partial \ln \mathcal{L}_{fh,k}(\boldsymbol{w})}{\partial \ln w_f} = -\tilde{\varepsilon}_{fh,k}$Finally, note that when export taxes are zero (which is case in our analysis in Section 5), $\bar{x} = 0$ and the formula for $\bar{\tau}$ reduces to that presented in the text—albeit in the main text we used $\bar{t}$ instead of τ to label the uniform term.

C Proof of Proposition 2

Here we build on our previous results to characterize the optimal tariff in a scenario where export taxes are unavailable but tariffs can be freely chosen across all industries. In this scenario, the vector of optimal tariffs should satisfy the system of F.O.C.s derived under

[28] The above equation implicitly assumes that $\partial (1+\bar{x}) / \partial w_h \approx 0$.

Equation 16:

$$\sum_g \left[\left(1 - \frac{1+\bar{\tau}}{1+t_g}\right) \left(\varepsilon_{fh,g}^{fh,k} + \eta_{fh,g} \frac{\partial \ln Y_h}{\partial \ln\left(1+t_k\right)}\right) \acute{\lambda}_{fh,g} \right] = 0, \text{ for all } k.$$

The trivial solution to the above system of first-order conditions (which involves K equations and unknowns) is $t_k = \bar{\tau}$ for all k. We can also characterize conditions that ensure the trivial solution, $t_k = \bar{\tau}_k$, is also the unique solution. To this end, recall our previous definitions of $\boldsymbol{B} \equiv \left[\acute{\lambda}_{fh,g} \left(\varepsilon_{fh,g}^{fh,k} + \eta_{fh,g} \frac{\partial \ln Y_h}{\partial \ln(1+t_k)} \right) \right]_{k,g}$ that is a $K \times K$ matrix and $\boldsymbol{\omega} \equiv \left[1 - \frac{1+\bar{\tau}}{1+t_k} \right]_k$ that is a $K \times 1$ vector. Using these definitions, the system of F.O.C.s can be expressed as $\boldsymbol{B\omega} = \boldsymbol{0}$. For $\boldsymbol{\omega} = \boldsymbol{0}$ to be the unique (and trivial) solution to $\boldsymbol{B\omega} = \boldsymbol{0}$, it suffices that

$$\det \boldsymbol{B} = \det \left[\acute{\lambda}_{fh,g} \left(\varepsilon_{fh,g}^{fh,k} + \eta_{fh,g} \frac{\partial \ln Y_h}{\partial \ln\left(1+t_k\right)} \right) \right] \neq 0.$$

Next, we need to derive $\bar{\tau}$, which can be done along the following steps:

$$\begin{aligned}
\bar{\tau} = \frac{\frac{\partial V_h}{\partial w_h} / \frac{\partial V_h}{\partial Y_h}}{\frac{\partial D_h}{\partial w_h}} &= \frac{\frac{\partial Y_h}{\partial w_h} + \sum_k \left(\frac{\partial V_h / \partial \tilde{p}_{hh,k}}{\partial V_h / \partial Y_h} \frac{\partial \tilde{p}_{hh,k}}{\partial w_h} \right)}{\frac{\partial \left(\sum_k p_{fh} q_{hf,k}\right)}{\partial w_h} - \frac{\partial \left(\sum_k \tilde{p}_{hf} q_{hf,k}\right)}{\partial w_h}} = \frac{\frac{\partial Y_h}{\partial w_h} - \sum_k \left(q_{hh,k} \frac{\partial \tilde{p}_{hh,k,}}{\partial w_h} \right)}{\frac{\partial \left(\sum_k p_{fh} q_{hf,k}\right)}{\partial w_h} - \frac{\partial \left(\sum_k \tilde{p}_{hf} q_{hf,k}\right)}{\partial w_h}} \\
&= \frac{w_h L_h + \sum_k \left(t_k \frac{\partial \left(p_{fh,k} q_{fh,k}\right)}{\partial \ln w_h} + x_k \frac{\partial \left(p_{hf,k} q_{hf,k}\right)}{\partial \ln w_h} \right) - \sum_k \tilde{p}_{hh,k} q_{hh,k}}{\frac{\partial \left(\sum_k p_{fh} q_{hf,k}\right)}{\partial w_h} - \frac{\partial \left(\sum_k \tilde{p}_{hf} q_{hf,k}\right)}{\partial w_h}}.
\end{aligned}$$

The second line in the above expression follows for Roy's identity: $\frac{\partial V_h / \partial \tilde{p}_{hh,k}}{\partial V_h / \partial Y_h} = -q_{hh,k}$. Noting that $x_k = 0$ for all k, $p_{ji,k} q_{ji,k} = w_j \mathcal{L}_{ji,k} \left(\boldsymbol{w}; \boldsymbol{t}, \boldsymbol{x}\right)$, and $\sum_k p_{ji,k} q_{ji,k} = w_j \mathcal{L}_{ji} \left(\boldsymbol{w}; \boldsymbol{t}, \boldsymbol{x}\right)$ (by the definition of labor demand), the above expression can be reformulated as

$$\bar{\tau} = \frac{w_h \mathcal{L}_{hf} + \bar{\tau} \frac{\partial \ln w_f \mathcal{L}_{fh}}{\partial \ln w_h}}{\frac{\partial w_f \mathcal{L}_{fh}}{\partial w_h} - \frac{\partial \sum_k (1+x_k) w_h \mathcal{L}_{hf,k}}{\partial w_h}} = \frac{1}{-\tilde{\varepsilon}_{hf} - 1},$$

where the last line follows from Definition D4, whereby

$$\begin{aligned}\tilde{\varepsilon}_{hf} &\equiv \partial \ln \mathcal{L}_{hf}\left(\boldsymbol{w};\boldsymbol{t},\boldsymbol{x}\right)/\partial \ln w_h \\ &= \sum_k \frac{\acute{r}_{hf,k}}{\acute{r}_{hf}}\tilde{\varepsilon}_{hf,k} = \sum_k \sum_g \frac{\acute{r}_{hf,k}}{\acute{r}_{hf}}\varepsilon_{hf,k}^{hf,g},\end{aligned}$$

denotes the elasticity of Foreign's demand for Home's labor, with $\acute{r}_{hf,k} \equiv p_{hf,k}q_{hf,k}/w_h L_h$ being the share of Home's (non-tax) revenue generated from sales to Foreign in industry k. The expression for $\bar{\tau}$, immediately implies the optimal tariff formula specified by Proposition 2: $1+\bar{t}^* = \frac{\tilde{\varepsilon}_{hf}}{1+\tilde{\varepsilon}_{hf}}$.

D Proof of Proposition 4

The optimal NRTB problem of the home country can be formulated as

$$\max_{(\mathbf{0},\mathbf{0},\boldsymbol{\tau};\boldsymbol{w})\in\mathbb{A}} \quad W_h\left(\mathbf{0},\mathbf{0},\boldsymbol{\tau};\boldsymbol{w}\right).$$

To tighten the notation, we henceforth use $W_h\left(\boldsymbol{\tau};\boldsymbol{w}\right) \equiv W_h\left(\mathbf{0},\mathbf{0},\boldsymbol{\tau};\boldsymbol{w}\right)$ to denote welfare arising from the imposition of NRTBs when revenue-raising taxes are restricted. The F.O.C. with respect to the NRTB in industry k can be stated as

$$\begin{aligned}\frac{\mathrm{d}W_h\left(\boldsymbol{\tau};\boldsymbol{w}\right)}{\mathrm{d}\left(1+\tau_k\right)} &= \frac{\partial V_h}{\partial Y_h}\left[\frac{\partial Y_h}{\partial\left(1+\tau_k\right)} + \frac{\partial Y_h}{\partial w_h}\frac{\mathrm{d}w_h}{\mathrm{d}\left(1+\tau_k\right)}\right] \\ &\quad + \sum_g \sum_{j=f,h}\left[\frac{\partial V_h}{\partial \tilde{p}_{jh,g}}\frac{\partial \tilde{p}_{jh,g}}{\partial\left(1+\tau_k\right)} + \frac{\partial V_h}{\partial \tilde{p}_{jh,g}}\frac{\partial \tilde{p}_{jh,g}}{\partial w_h}\frac{\mathrm{d}w_h}{\mathrm{d}\left(1+\tau_k\right)}\right] = 0.\end{aligned}$$

Noting that (i) $\partial Y_h/\partial\left(1+\tau_k\right) = 0$, (ii) $\partial \tilde{p}_{hh,g}/\partial\left(1+\tau_k\right) = 0$ for all g, (iii) $\partial \tilde{p}_{fh,g}/\partial\left(1+\tau_k\right) = 0$ if $g \neq k$ or, and (iv) applying the implicit function theorem to derive

$dw_h/d\,(1+\tau_k)$, the F.O.C. can be written as:

$$\frac{\mathrm{d}W_h\,(\boldsymbol{\tau};\boldsymbol{w})}{\mathrm{d}\ln\,(1+\tau_k)}=\frac{\partial V_h}{\partial Y_h}\left\{\frac{\partial V_h/\partial\tilde{p}_{fh,k}}{\partial V_h/\partial Y_h}\frac{\partial\tilde{p}_{fh,k}}{\partial\ln\,(1+\tau_k)}-\frac{\frac{\partial V_h}{\partial w}/\frac{\partial V_h}{\partial Y_h}}{\frac{\partial D_h(\boldsymbol{\tau};\boldsymbol{w})}{\partial w}}\left(p_{fh,k}\frac{\partial q_{fh,k}}{\partial\tilde{p}_{fh,k}}\frac{\partial\tilde{p}_{fh,k}}{\partial\ln\,(1+\tau_k)}\right)\right\}=0,$$

where, as before, $\frac{\partial V_h}{\partial w_h}=\frac{\partial Y_h}{\partial w_h}\frac{\partial V_h}{\partial Y_h}+\sum_g\sum_{j=h,f}\left(\frac{\partial V_h}{\partial\tilde{p}_{jh,g}}\frac{\partial\tilde{p}_{jh,g}}{\partial w_h}\right)$. The above condition can be simplified as follows:

$$\frac{\mathrm{d}W_h\,(\boldsymbol{\tau};\boldsymbol{w})}{\mathrm{d}\ln\,(1+\tau_k)}=-\frac{\partial V_h}{\partial Y_h}p_{fh,k}q_{fh,k}\left(1+\bar{\tau}\varepsilon_{fh,k}\right)=0.$$

Given its definition, $\bar{\tau}$ can be calculated as

$$\begin{aligned}
\bar{\tau}&=\frac{\frac{\partial V_h}{\partial w_h}/\frac{\partial V_h}{\partial Y_h}}{\frac{\partial D_h(\boldsymbol{\tau};\boldsymbol{w})}{\partial w_h}}=\frac{\frac{\partial Y_h}{\partial w_h}+\sum_k\left(\frac{\partial V_h/\partial p_{hh,k}}{\partial V_h/\partial Y_h}\frac{\partial p_{hh,k}}{\partial w_h}\right)}{\frac{\partial\left(\sum_k p_{fh,k}q_{fh,k}\right)}{\partial w_h}-\frac{\partial\left(\sum_k p_{hf,k}q_{hf,k}\right)}{\partial w_h}}=\frac{\frac{\partial Y_h}{\partial w_h}-\sum_k\left(q_{hh,k}\frac{\partial p_{hh,k,}}{\partial w_h}\right)}{\frac{\partial\left(\sum_k p_{fh,k}q_{fh,k}\right)}{\partial w_h}-\frac{\partial\left(\sum_k p_{hf,k}q_{hf,k}\right)}{\partial w_h}}\\
&=\frac{Y_h\frac{\partial\ln Y_h}{\partial\ln w_h}-\sum_k\left(p_{hh,k}q_{hh,k}\frac{\partial\ln p_{hh,k}}{\partial\ln w_h}\right)}{\sum_k\left(p_{fh,k}q_{fh,k}\right)\frac{\partial\left(\sum_k p_{fh,k}q_{fh,k}\right)}{\partial w_h}-\sum_k\left(p_{hf,k}q_{hf,k}\right)\frac{\partial\left(\sum_k p_{hf,k}q_{hf,k}\right)}{\partial w_h}}\\
&=\frac{w_hL_h-\sum_k p_{hh,k}q_{hh,k}}{\left(p_{hf,k}q_{hf,k}\right)\left(\frac{\partial\left(\sum_k p_{fh,k}q_{fh,k}\right)}{\partial w_h}-\frac{\partial\left(\sum_k p_{hf,k}q_{hf,k}\right)}{\partial w_h}\right)}=\frac{\left(p_{hf,k}q_{hf,k}\right)}{\left(p_{hf,k}q_{hf,k}\right)\left(\frac{\partial\left(\sum_k p_{fh,k}q_{fh,k}\right)}{\partial w_h}-\frac{\partial\left(\sum_k p_{hf,k}q_{hf,k}\right)}{\partial w_h}\right)}\\
&=\frac{1}{\frac{\partial\mathcal{L}_{fh}(\boldsymbol{w};\boldsymbol{\tau})}{\partial w_h}-\frac{\partial\mathcal{L}_{hf}(\boldsymbol{w};\boldsymbol{\tau})}{\partial w_h}}=-\frac{1}{1+\tilde{\varepsilon}_{fh}+\tilde{\varepsilon}_{hf}},
\end{aligned}$$

with the last line following from our earlier derivation that (per D4) $\partial\mathcal{L}_{fh}\,(\boldsymbol{w};\boldsymbol{\tau})\,/\partial w_h=-\tilde{\varepsilon}_{fh}$ and $\partial\ln\mathcal{L}_{hf}\,(\boldsymbol{w};\boldsymbol{\tau})\,/\partial\ln w_h=1+\tilde{\varepsilon}_{hf}$. Plugging $\bar{\tau}$ from above expression back into the F.O.C., implies the following:

$$\begin{cases}\frac{\partial W_h}{\partial\ln(1+\tau_k)}>0 & \text{if}\quad \varepsilon_{fh,k}<1+\tilde{\varepsilon}_{hf}+\tilde{\varepsilon}_{fh}\\ \frac{\partial W_h}{\partial\ln(1+\tau_k)}<0 & \text{if}\quad \varepsilon_{fh,k}>1+\tilde{\varepsilon}_{hf}+\tilde{\varepsilon}_{fh}\end{cases}$$

Note the imposition of τ_k reduces $q_{fh,k}$. So if demand is super-convex, i.e., $\partial\varepsilon_{fh,k}/\partial q_{fh,k} > 0$, then the above conditions imply following formula for optimal NRTBs:

$$\tau_k = \begin{cases} \infty & \text{if} \quad \varepsilon_{fh,k} < 1 + \tilde{\varepsilon}_{hf} + \tilde{\varepsilon}_{fh} \\ 0 & \text{if} \quad \varepsilon_{fh,k} > 1 + \tilde{\varepsilon}_{hf} + \tilde{\varepsilon}_{fh} \end{cases}.$$

The condition that $\partial\varepsilon_{fh,k}/\partial q_{fh,k} > 0$ is widely-known as Marshall's Second Law of Demand, and is satisfied in an important class of trade models.

E Additional Tables

Table 2: *List of countries in quantitative analysis*

Country name	WIOD code	Basic aggregation
Australia	AUS	Australia
Brazil	BRA	Brazil
Canada	CAN	Canada
China	CHN	China
Indonesia	IDN	Indonesia
India	IND	India
Japan	JPN	Japan
Korea	KOR	Korea
Mexico	MEX	Mexico
Russia	RUS	Russia
Turkey	TUR	Turkey
Taiwan	TWN	Taiwan
United States	USA	United States
Austria	AUT	European Union
Belgium	BEL	
Bulgaria	BGR	
Cyprus	CYP	
Czech Republic	CZE	
Germany	DEU	
Denmark	DNK	
Spain	ESP	
Finland	FIN	
France	FRA	
United Kingdom	GBR	
Greece	GRC	
Hungary	HUN	
Ireland	IRL	
Italy	ITA	
Netherlands	NLD	
Poland	POL	
Portugal	PRT	
Romania	ROM	
Slovakia	SVK	
Slovenia	SVN	
Sweden	SWE	
Estonia	EST	
Latvia	LVA	
Lithuania	LTU	
Luximburg	LUX	
Malta	MLT	
Rest of the World	RoW	Rest of the World

__Table 3:__ List of industries in quantitative analysis

WIOD Sector	**Sector's Description**	**Trade Ealsticity** (Caliendo-Parro)
1	Agriculture, Hunting, Forestry and Fishing	8.11
2	Mining and Quarrying	15.72
3	Food, Beverages and Tobacco	2.55
4	Textiles and Textile Products Leather and Footwear	5.56
5	Wood and Products of Wood and Cork	10.83
6	Pulp, Paper, Paper , Printing and Publishing	9.07
7	Coke, Refined Petroleum and Nuclear Fuel	51.08
8	Chemicals and Chemical Products	4.75
9	Rubber and Plastics	1.66
10	Other Non-Metallic Mineral	2.76
11	Basic Metals and Fabricated Metal	7.99
12	Machinery, Nec	1.52
13	Electrical and Optical Equipment	10.60
14	Transport Equipment	0.37
15	Manufacturing, Nec; Recycling	5.00
16	Electricity, Gas and Water Supply Construction Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods Hotels and Restaurants Inland Transport Water Transport Air Transport Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies Post and Telecommunications Financial Intermediation Real Estate Activities Renting of M&Eq and Other Business Activities Education Health and Social Work Public Admin and Defence; Compulsory Social Security Other Community, Social and Personal Services Private Households with Employed Persons	100