# Global Supply Chains and Trade Policy*

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**Abstract**

How do global supply chain linkages modify countries' incentives to impose unilateral import protection? Are these linkages empirically important determinants of tariffs and other policy barriers to trade? To answer these questions, we integrate supply chain linkages into the terms-of-trade model of trade policy, and we develop testable predictions that relate observed bilateral final goods tariffs to domestic and foreign value-added content. We test the predictions using a new database of bilateral applied tariffs and value-added content derived from global input-output tables for 14 major economies and 15 sectors over the 1995-2009 period. We find that domestic content in foreign final goods production lowers bilateral tariffs on final goods imports, consistent with the theory. We also find that foreign value added in domestic final goods production raises import protection for final goods. Both results hold for non-tariff barriers as well.

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In the modern global economy, final goods are typically produced by combining domestic and foreign value added via offshore production or global supply chains. Foreign value added now accounts for more than 20% of the value of final manufacturing output in many countries, and more than 50% in some countries and sectors. At the same time, imported final goods contain significant domestic value added, as exported intermediate inputs return home embodied in foreign final goods.

These global supply chain linkages have important implications for the conduct of trade policy. First, taxing imports hurts upstream domestic firms that supply inputs to foreign producers, because import barriers depress the value of foreign goods produced and hence revenue accruing to domestic input suppliers. This mechanism dampens government incentives to apply import protection on final goods. Second, when domestic firms use foreign value added in local final goods production, some of the benefits of an import tariff are passed back through the supply chain to foreign input suppliers. This also alters the calculus of import protection, encouraging protection if foreign interests have strong political influence on local trade policy, and discouraging it if foreign interests are politically weak.

Despite these observations, global supply chains are absent in most theoretical and empirical analysis of trade policy.[1] This omission is particularly conspicuous in light of the growing importance of global supply chains as conduits of trade. It is also out of step with policy discussions, in which supply chain concerns are front and center in current trade negotiations.[2]

In this paper, we integrate supply chain linkages into the workhorse terms-of-trade model of trade policy, and use the resulting framework to develop testable predictions that relate observed bilateral final goods tariffs to measures of domestic content embodied in foreign final goods and foreign value added embodied in domestic final goods. We then develop a new database that combines bilateral applied tariffs with data on value-added contents derived from global input-output tables to examine these predictions for 14 major economies and 15 sectors over the 1995-2009 period. We find strong evidence that domestic content in foreign final goods production lowers bilateral tariffs on final goods imports, consistent with the theory. We also find that foreign value added in domestic final goods production raises import protection for final goods, consistent with foreign input suppliers having significant political weight in domestic policy formulation. Further, we show that both results hold for governments use of non-tariff barriers as well.

Our first contribution is theoretical: we extend the canonical terms-of-trade theory to

[1] Exceptions include Blanchard (2007) Blanchard (2010), Antràs and Staiger (2012), and Blanchard and Matschke (2014), which we discuss further below.

[2] As evidence of the importance of supply chains in policy discussions, see the WTO's "Made in the World Initiative" and the 2014 World Trade Report. See also Hoekman (2014).

include cross-border supply chain linkages via trade in value-added fragments in production. Specifically, we develop a model in which final goods are produced by combining domestic and foreign value added. Trade in value added components drives a wedge between national income and the value of domestic final goods production: some revenue from domestic final goods production is paid to foreigners, while some foreign final goods revenue is paid to home residents. This re-conceptualization of the production process changes the mapping from prices to income, and hence welfare, relative to standard models. As a result, it alters government incentives to apply import protection.

To illustrate the mechanics clearly, we first derive the optimal tariff for final goods in a two-country, two good setting, consistent with the approach in Bagwell and Staiger (1999). After first illustrating how global supply chain linkages modify the incentives for protection in the two-by-two benchmark, we then extend the model to include many countries, many goods, and a flexible set of political economy motives. We then use the theory to derive testable predictions linking bilateral trade policy and value added that we take to data.

We show that when foreign value added in domestic production and/or domestic value added in foreign production are non-zero, the optimal tariff deviates from the standard inverse export elasticity supply rule for two distinct reasons. The first is that high domestic content in foreign final goods production puts downward pressure on optimal tariffs, because it dampens a country's incentive to manipulate its terms of trade. Put simply, using tariffs to push down foreign prices hurts upstream domestic producers who supply value-added fragments in foreign production.[3] The second channel works through domestic prices, rather than the terms of trade. High foreign value added embodied in domestic production reduces a government's incentives to impose import protection against *all* trading partners, though the influence of this force on bilateral tariffs varies across partners depending on bilateral final goods import volumes. Finally, we show that allowing a government to value political economy (distributional) concerns, and not just maximize national welfare, strengthens the first channel, and weakens (or even overturns) the second.[4]

By integrating supply chain linkages into the terms-of-trade theory of policy determination, our findings complement two strands of related theoretical work. First, the mechanics regarding how value-added content influences optimal tariffs parallel the role of international ownership and foreign direct investment in modifying optimal tariffs, as described in Blanchard (2010). Foreign ownership recasts the mapping from prices to income in a manner similar to the value-added linkages we focus on here. At the same time, the quantitative

[3]This channel is fundamentally bilateral: bilateral optimal tariffs depend on how much domestic value added is embodied in final goods produced by the particular partner country to which protection is applied.

[4]In particular, if foreign value added receives a large enough weight the government's objective function, then import tariffs may rise with the amount of foreign value added in domestic production.

importance of value-added linkages is potentially far greater than that of ownership/FDI, due to the magnitude of input trade. Second, our attention to how global supply chains alter terms-of-trade arguments for protection complements Antràs and Staiger (2012), who emphasize that bilateral bargaining among supply chain partners alters the mapping from tariffs to prices, and therefore optimal trade policy. While this paper highlights different mechanisms, our insights extend to a broad set of existing trade policy models in which terms-of-trade externalities are paramount.

Our second contribution is to combine data on bilateral protection and valued added contents to test key predictions of the theory and to quantify the role of supply chain linkages. Because policy is constrained by institutions, we focus on dimensions of policy over which governments have scope to implement discretionary policy.[5] We first examine bilateral applied tariffs, the focus of the theory, and then examine the use of temporary trade barriers (antidumping duties, countervailing duties, and safeguards) as well.[6]

Our approach to analyzing these observed bilateral tariffs is guided by both the theory and important institutional features of the multilateral trading system. First, we use the theory to guide our specifications and choice of controls. In the theory, tariffs depend on domestic value added in foreign final goods and foreign value added in domestic final goods, along with the standard inverse export supply elasticity and domestic political economy forces. We focus first on identifying the role of domestic value added in foreign production, by using flexible fixed-effects control for export supply elasticities and political economy. Then we turn to a second specification based on the theory to identify the role of foreign value added in domestic production. Throughout the analysis, we measure value added contents using input-output methods and data from the World Input-Output Database.

Second, we tailor our approach to respect several important institutional features of the multilateral trading system. While governments have some discretion to offer preferential bilateral tariffs via various trade preference programs (e.g., Article XXIV or the Enabling Clause of the GATT), they are subject to several important constraints. Put differently, though we model the behavior of optimal unilateral tariffs, our empirical strategy explicitly recognizes that observed bilateral tariffs cannot always be set at the optimal level.

One constraint is the most favored nation (MFN) rule under the GATT, which caps bilateral tariffs for many trading partners at levels below the unilaterally optimal tariff.

[5]Our study is in the tradition of earlier work examining unconstrained dimensions of policy, including Trefler (1993), Goldberg and Maggi (1999), Gawande and Krishna (2003), Broda, Limão, and Weinstein (2008), Bown and Crowley (2013), and Blanchard and Matschke (2014), among others.

[6]We build up bilateral data on preferential tariffs at the industry level from product-level applied bilateral tariff data, which reflect the actual application of preferences (including product-level exclusions from preferential schemes), and find that preferential tariffs are plentiful in the data. We draw on existing data on temporary trade barriers from Bown (2014).

Thus, we can observe bilateral optimal tariffs only up to, but not above, the MFN threshold. We use non-linear methods to address this partial non-observability, or censoring, problem. A second constraint is that some bilateral tariffs are set via bilateral negotiation, through bilateral or regional trade agreements (RTAs). We discuss various cross-cutting concerns about using these tariffs in our analysis, some which argue for using them in our analysis and some which argue against. In the end, we show that our results hold both controlling for RTAs and when we exclude RTAs entirely.

To summarize our results, we find that higher domestic value added in foreign production tends to lower applied bilateral tariffs. This result holds across a variety of specifications, controlling for confounding effects using both observable proxies and fixed effects. It becomes stronger when we instrument for domestic value added content. It also becomes stronger when we correct for censoring. This is intuitive: since the MFN rule constrains the response of observed bilateral applied tariffs, optimal bilateral tariffs are more sensitive to value added content than observed tariffs. In contrast to these results, we find that higher foreign value added in domestic final goods production tends to raise domestic protection. Interpreted via the theory, this suggests that upstream foreign producers exert political influence over trade policy, wherein they lobby for higher final goods tariffs on the goods that embody their value added.

Finally, we examine data on the use of temporary trade barriers (TTBs), where discretion is paramount, to corroborate our findings for tariffs. We find that bilateral TTB coverage ratios respond to value added content in exactly the same way as do bilateral applied tariffs. Thus, across the board, our empirical exercises find strong evidence consistent with the theory, and demonstrate the empirical importance of particular channels through which global supply chains shape governments' trade policy decisions.

In addition to highlighting the role of global supply chains, our empirical results contribute to the existing empirical trade policy literature in two more ways. First, our evidence linking the domestic value added content of imports to bilateral tariffs fits into an important literature documenting that terms-of-trade concerns matter for trade policy formulation [Broda, Limão, and Weinstein (2008), Bagwell and Staiger (2011), Ludema and Mayda (2013), Bown and Crowley (2013)]. To our knowledge, we are the first to demonstrate the relevance of terms of trade theory in bilateral tariff setting.

Our empirical contribution also sheds light on the forces that determine *bilateral* trade policy. It complements Bown and Crowley (2013), who document the importance of terms-of-trade influences in U.S. application of bilateral antidumping and safeguard measures, and Blanchard and Matschke (2014), who show that the United States is more likely to offer preferential market access to destinations that host US multinational affiliates that sell

goods back to the US.

Finally, this paper contributes to a growing literature applying global input-output methods to measure the value-added content of trade [Johnson and Noguera (2012), Koopman, Wang, and Wei (2014), Los, Timmer, and de Vries (2014)]. Relative to that literature, this paper is not about measurement per se, but rather about quantifying the economic consequences of value-added linkages in production.

The remainder of this paper proceeds as follows. Section 1 presents the analytical framework, arriving at an expression for bilateral optimal tariffs as a function of value-added contents. Section 2 outlines our empirical strategy for taking the theory to data. We present the value-added, tariff, and TTB data in Section 3, and provide our estimates in Section 4. Section 5 concludes.

# 1 Theoretical Framework

In this section, we show how global supply chain linkages change the structure of optimal tariffs. We present the theory in two stages, moving from a broad conceptualization of the theory to the concrete result that underlies our empirical analysis. In Section 1.1, we introduce trade in value added to the canonical 2x2 general equilibrium setting and derive the optimal (national income maximizing) tariff. Section 1.2 then introduces political economy motivations and extends the framework to a many-good, many country setting. We derive an expression for sector-specific optimal bilateral tariffs on final goods, which is the basis for our empirical investigations. A short final section rewrites this bilateral tariff expression in terms of the measurable value-added content of final goods.

## 1.1 The Optimal Tariff: 2x2 Model

To fix ideas, we build on a standard derivation of the optimal tariff, first formalized by Johnson (1954) and updated by Bagwell and Staiger (1999).

Consider the optimal tariff problem of a country, 'Home', which is large in world markets. Home produces and trades two (final) goods, $x$ and $y$ under perfectly competitive markets and subject to increasing opportunity costs. We refer to the rest of the world as 'Foreign', which is subject to the same assumptions and has variables denoted by asterisks ($^*$). Let good $y$ be the numeraire so that the relative final goods price of $x$ measured in units of good $y$ is $p \equiv \frac{p_x}{p_y}$, and take $x$ to be Home's natural import good, so that $p = \tau p^*$, where $\tau$ is one plus Home's ad-valorem import tariff and $p^*$ denotes the relative price of $x$ in the rest

of the world.[7] Preferences satisfy Gorman form, so that aggregate national welfare can be summarized by a single, representative agent with indirect utility given by $V(p, I)$, where $I$ represents national income in terms of the numeraire.

We augment the standard modeling structure by introducing global supply chain linkages via trade in value-added. Each country is endowed with value-added, which can be used in the production of final goods at home and/or abroad. We adopt a reduced form production structure in which final goods are produced using a composite of value added from each country. There are no other factors of production.

As a notational convention, we let superscripts denote the location of activity and subscripts reference sector and value added origin. Final output in goods sector $s$ produced in country $c$ is then given by the production function:

$$q_s^c = f_s^c(\nu_{sh}^c, \nu_{s*}^c) \quad \forall s \in \{x, y\}, c \in \{h, *\}, \tag{1}$$

where $\nu_{sh}^c$ ($\nu_{s*}^c$) denotes the total Home (Foreign) value added content embodied in the production of final goods in sector $s$ and country $c$. We are intentionally agnostic about the underlying production structure by which value added is transformed into final goods, but we implicitly assume that value added is imperfectly substitutable across end uses and source countries, and is subject to trade frictions that prevent returns to value added from a given source country from equalizing across destinations in equilibrium.[8]

All revenue from final goods production is distributed among the value added components used in production. Using $r_{sh}^c$ ($r_{s*}^c$) to denote the per-unit return to Home (Foreign) value added used in production of final good $s$ in country $c$, zero profit conditions for production of each final good at Home and abroad imply:

$$\begin{aligned} pq_x^h &= r_{xh}^h \nu_{xh}^h + r_{x*}^h \nu_{x*}^h \qquad & q_y^h &= r_{yh}^h \nu_{yh}^h + r_{y*}^h \nu_{y*}^h \\ p^* q_x^* &= r_{xh}^* \nu_{xh}^* + r_{x*}^* \nu_{x*}^* \qquad & q_y^* &= r_{yh}^* \nu_{yh}^* + r_{y*}^* \nu_{y*}^* \end{aligned} \tag{2}$$

National income is then given by sum of the total return to a country's value added (used in final goods production at home or abroad) and tariff revenue. For the Home country:

$$I = \sum_{s \in \{x,y\}} \left( r_{sh}^h \nu_{sh}^h + r_{sh}^* \nu_{sh}^* \right) + \underbrace{(p - p^*) M_x(p, I; \vec{\nu})}_{\equiv R(\vec{p}, I; \vec{\nu})}, \tag{3}$$

[7] For simplicity, assume that the rest of the world sets no tariffs, so that $p^* = p^w$; i.e. $\tau^* \equiv 1$.

[8] Imperfect substitution in value added across end uses would be consistent, for instance, with a specific factors production structure. It could also arise if value added is used to produce intermediate inputs, which are themselves imperfectly substitutable in production of final goods.

where $R(\cdot)$ represents tariff revenue and $M_x(\cdot) \equiv d_x^h(p, I) - q_x^h(\nu_{xh}^h, \nu_{x*}^h)$ denotes home imports of good $x$, with $d_x^h(p, I)$ indicating home's demand for good $x$ as a function of local prices and income.[9] Substituting from the conditions in (2), national income can be rewritten in more familiar terms:

$$I = pq_x^h(\vec{\nu}) + q_y^h(\vec{\nu}) + R(\vec{p}, I; \vec{\nu}) - \underbrace{\sum_{s\in\{x,y\}} r_{s*}^h \nu_{s*}^h}_{\equiv \psi_*^h(\vec{r};\vec{\nu})} + \underbrace{\sum_{s\in\{x,y\}} r_{sh}^* \nu_{sh}^*}_{\equiv \psi_h^*(\vec{r};\vec{\nu})}. \tag{4}$$

The first three components of the expression mirror the traditional case in which national income can be written as the value of domestic final goods output measured at local prices, plus tariff revenue. The last two components are new, and represent the revenue from local final goods production that is paid to *Foreign value added embodied in Home final goods production* ($\psi_*^h$) and the total returns paid to *Home value added embodied in Foreign final goods production* ($\psi_h^*$). Each depends on both the pattern ($\vec{\nu}$) and price ($\vec{r}$) of value added embodied in final goods production in both sectors $x$ and $y$, at Home and abroad. In equilibrium, these depend in turn on final goods prices according to $\vec{r} = \vec{r}(\vec{p}, \vec{\nu}(\vec{r}(\vec{p}))) = \vec{r}(\vec{p})$ and $\vec{\nu} = \vec{\nu}(\vec{r}(\vec{p})) = \vec{\nu}(\vec{p})$, where we use $\vec{p} \equiv (p, p^*)$ to denote the vector of final goods prices at Home and abroad. Accordingly, national income may be summarized in terms of Home and Foreign final goods prices only, $I \equiv I(p, p^*)$, as in Bagel and Staiger (1999).

We are now ready to derive the optimal tariff. An apolitical government chooses the optimal tariff to maximize the indirect utility of the representative consumer according to:

$$\tau^o = \arg\max_{\tau} \qquad V\big(p(\tau, p^*), I(p(\tau, p^*), p^*)\big). \tag{5}$$

The associated first order condition is:

$$V_\tau = V_p \frac{dp}{d\tau} + V_I \left\{ \frac{\partial I(p, p^*)}{\partial p} \frac{dp}{d\tau} + \frac{\partial I(p, p^*)}{\partial p^*} \frac{dp^*}{d\tau} \right\} = 0, \tag{6}$$

where $V_p \equiv \frac{\partial V(p,I)}{\partial p}$, and $V_I \equiv \frac{\partial V(p,I)}{\partial I}$. Applying Roy's identity, and substituting the derivatives of (4) with respect to $p$ and $p^*$ into (6) yields the implicit form of the optimal tariff, $t^o$:

$$V_\tau = V_I \left\{ \underbrace{t^o p^* \frac{dM_x}{d\tau} - M_x \frac{dp^*}{d\tau}}_{\text{standard TOT motive}} - \frac{d\psi_*^h}{d\tau} + \frac{d\psi_h^*}{d\tau} \right\} = 0. \tag{7}$$

[9] This income definition presumes that domestic residents own claims to all income paid to domestic factors (i.e., value added). In national income accounting terminology, this is like saying that gross domestic product equals gross domestic income.

The expression in the under-brace reflects the standard terms of trade cost shifting motive, which is standard in the existing literature. The next two terms capture the impact of Foreign value added embodied in Home final goods production and Home value added in Foreign final goods production, respectively.

Solving for the optimal tariff, we note that in equilibrium home imports must equal foreign exports, so that by the implicit function theorem, $\frac{dM_x}{d\tau} = \frac{dE_x^*}{dp^*}\frac{dp^*}{d\tau}$. Thus:

$$t^o p^* \frac{dE_x^*}{dp^*}\frac{dp^*}{d\tau} = \left[E_x^*\frac{dp^*}{d\tau} - \Delta\psi_h^*\frac{dp^*}{d\tau} - \Delta\psi_*^h\frac{1}{|\lambda|}\frac{dp^*}{d\tau}\right], \tag{8}$$

where $\lambda \equiv \frac{dp^*}{d\tau}\big/\frac{dp}{d\tau} < 0$[10] and the terms $\Delta\psi_*^h$ and $\Delta\psi_h^*$ represent the effect of price changes on the total return to foreign value added embodied in domestic production and domestic value added embodied in foreign production, respectively. Specifically, we define the terms:[11]

$$\Delta\psi_h^* \equiv \sum_{s\in\{x,y\}} \underbrace{\left[\frac{dr_{sh}^*}{dp^*}\nu_{sh}^* + \left(\frac{d\nu_{sh}^*}{dp^*} - \frac{d\nu_{sh}^*}{dp}\frac{1}{|\lambda|}\right)r_{sh}^*\right]}_{(+)\text{ for } s=x;\ (-)\text{ for } s=y} \tag{9}$$

$$\Delta\psi_*^h \equiv \sum_{s\in\{x,y\}} \underbrace{\left[\frac{dr_{s*}^h}{dp}\nu_{s*}^h + \left(\frac{d\nu_{s*}^h}{dp} - \frac{d\nu_{s*}^h}{dp^*}|\lambda|\right)r_{s*}^h\right]}_{(+)\text{ for } s=x;\ (-)\text{ for } s=y}. \tag{10}$$

With some manipulation, we can now write the optimal tariff:

$$t^o = \frac{1}{\hat{\epsilon}_x^*}\left(1 - \overbrace{\frac{\Delta\psi_h^*}{M_x}}^{\text{dom. va. abroad}} - \overbrace{\frac{\Delta\psi_*^h}{|\lambda|M_x}}^{\text{for. va. at home}}\right), \tag{11}$$

where $\hat{\epsilon}_x^*$ is foreign export supply elasticity.[12]

Equation (11), together with (9) and (10), traces out the effects of value added trade on the optimal tariff on final goods. Trade in value added enters the optimal tariff expression in two ways.[13] First, an import tariff on $x$ lowers the return to Home's value added embodied

[10] As in Bagwell and Staiger (1999), we assume that neither the Lerner nor Metzler paradoxes arise, so that $\frac{dp^*}{d\tau} < 0 < \frac{dp}{d\tau}$.

[11] Alternatively, in vector notation, $\Delta\psi_h^* \equiv \frac{D\psi_h^*(\vec{p})\cdot\nabla\vec{p}(\tau)}{dp^*/d\tau}$ and $\Delta\psi_*^h \equiv \frac{D\psi_*^h(\vec{p})\cdot\nabla\vec{p}(\tau)}{dp/d\tau}$.

[12] In the presence of value added trade, export supply elasticity includes any potential foreign income effects from changes in the return to foreign value added content in the home economy. Thus, $\hat{\epsilon}_x^* \equiv \epsilon_x^* + \frac{\partial E_x^*(p^*,I^*;\vec{\nu})}{\partial I^*}\cdot DI_{\vec{r}^h}^*\nabla\vec{r}_p^h\frac{p^*}{\lambda E_x^*}$, where $\epsilon_x^* \equiv \frac{p^*}{E_x^*}\frac{\partial E_x^*(p^*,I^*)}{\partial p^*}$ is the direct analog to the trade elasticity in conventional models. See Blanchard (2010) pp. 66-67.

[13] It is important to recognize that the terms $\Delta\psi_h^*$ and $\Delta\psi_h^*$ capture the impact of price changes on the returns to value added embodied in both final goods, $x$ and $y$. When the local relative price of $x$ rises, the total return to value added embodied in local $x$ production rises. This implies that the optimal tariff will

in foreign $x$ production (via $\Delta\psi_h^*$). When a large country imposes an import tariff, foreign export prices fall; when foreign exports embody domestic value added content, some of the cost of the tariff will be borne by domestic value added producers. Thus, a large importing country is made to internalize some of the negative terms of trade externality, and the optimal tariff falls. Second, an import tariff raises the return to foreign value added embodied in Home's production of $x$ (via $\Delta\psi_*^h$). Foreign value added embodied in domestic production also reduces the optimal tariff, but not through the terms of trade externality. Rather it operates through a new cost-shifting margin: by reducing its tariffs, the government can lower prices for its domestic consumer constituents at the expense of upstream foreign value added suppliers. Both terms enter as counterweights to the standard terms of trade motive reflected in the trade volume, $M_x$.

## 1.2 Politically Motivated Optimal Bilateral Tariffs

In preparing to take (11) to the data, we must make several modifications to the basic theory. The first is to extend the framework to include many sectors and many countries, and allow governments to set optimal bilateral tariffs at the sectoral level. The second is to introduce the potential for political economy motives in tariff setting. In doing so, we follow the literature in adopting a tractable partial equilibrium set-up with a numeraire sector, quasi-linear preferences, and segmented markets, as in Grossman and Helpman (1994), Broda, Limão, and Weinstein (2008), and Ludema and Mayda (2013).

Define the set of countries and non-numeraire sectors according to $\mathcal{C} = \{1, ..., C\}$ and $\mathcal{S} = \{1, ..., S\}$ respectively, where both $C$ and $S$ may be large. The numeraire good, $s = 0$, is freely traded so that $p_0^c = 1 \forall c$. Each country is endowed with homogenous labor and differentiated value added inputs, with population normalized to one. Preferences are identical and quasi-linear, given by:

$$U^i = d_0^i + \sum_s u_s(d_s^i) \quad \forall i \in \mathcal{C}, \tag{12}$$

where $d_s^i$ represents consumption of good $s$ in country $i$, and utility over the non-numeraire goods is additively separable across goods, differentiable, and strictly concave. Consumption is chosen to maximize utility subject to the budget constraint $d_0^i + \sum_s p_s^i d_s^i \leq I^i$.

be lower, the greater is Home's value added embodied in Foreign $x$ production *and* the greater is Foreign value added embodied in Home $x$ production. At the same time, an offsetting general equilibrium effect via good $y$ captures the impact of an increase in the local relative price of good $x$ on value added embodied in production of other goods; in the two good setting, this effect is necessarily negative and would counter the tariff liberalizing effect of value added embodied in good $x$. For example, if all traded value added trade embodied in good $x$, then $\Delta\psi_h^*$ and $\Delta\psi_h^* > 0$; if instead all traded value added trade was embodied in good $y$, then $\Delta\psi_h^*$ and $\Delta\psi_h^* < 0$. In the next section, we adopt conventional partial equilibrium assumptions that eliminate the possibility of offsetting general equilibrium effects.

The numeraire good is produced under constant returns to scale using only homogeneous labor, while production in non-numeraire sectors requires both labor and a composite (sector-country specific) value added component that may be sourced locally and/or from abroad. To maintain the partial equilibrium setting, we take the pattern of physical value added as fixed and exogenous, but allow the price paid to value added to vary as before.[14]

Value added captures all residual profit (quasi-rents) from production in the sector and location in which it is used. Defining the total sector specific quasi-rent to production of final goods in sector $x$ in country $j$ by $\pi_x^j$, we then have that:

$$\pi_x^j(p_x^j) = p_x^j q_x^j - w l_x^j = \sum_{c \in \mathcal{C}} r_{xc}^j \nu_{xc}^j, \tag{13}$$

where $w = 1$ by earlier assumptions and $l_x^j$ is the (local) labor used in production of good $x$ in country $j$. Under our assumptions, notice that the return to value added can be written as a function of only the local price of the final good where it is used for production; i.e. $r_{xc}^j \equiv r_{xc}^j(p_x^j)$.

As in the baseline model, we use $\psi_i^*$ ($\psi_*^i$) to denote total domestic (foreign) value added embodied in foreign (domestic) production from the perspective of any given country $i \in C$, where:

$$\psi_i^*(\vec{p};\vec{\nu}) \equiv \sum_{s \in S} \psi_{si}^*(\vec{p_s^*}) \equiv \sum_{s \in S} \sum_{c \neq i} r_{si}^c \nu_{si}^c \tag{14}$$

$$\psi_*^i(\vec{p};\vec{\nu}) \equiv \sum_{s \in S} \psi_{s*}^i(\vec{p_s^i}) \equiv \sum_{s \in S} \sum_{c \neq i} r_{sc}^i \nu_{sc}^i. \tag{15}$$

Following Ludema and Mayda (2013), we allow the government objective function to assign welfare weights to the different claimants on quasi-rents from home and foreign production in each sector.[15] Formally, we assume that the politically motivated government of country $i$ maximizes:

$$G^i = W^i + \sum_s [\delta_s^i \pi_s^i(p_s^i) + \delta_{s*}^i \psi_{s*}^i(p_s^i) + \delta_{si}^* \psi_{si}^*(p_s^*)], \tag{16}$$

where $W$ is utilitarian social welfare and $\{\delta_s^i, \delta_{s*}^i, \delta_{si}^*\}$ represent the weights (relative to aggregate social welfare) that the government places on the quasi-rents paid to, respectively, all value added used in home-located production in sector $s$, foreign owners of home-located

[14] Allowing value added to move across sectors and countries introduces cross-country, cross-sector production spillovers.

[15] These weights could be the result of lobbying, as in Grossman and Helpman (1994), Broda, Limão, and Weinstein (2008), etc., but they are also consistent with earlier political economy models.

value added used in sector $s$, and home owners of foreign-located value added used in sector $s$.[16] In principle, these welfare weights may be positive, zero, or negative, but standard political economy/lobbying arguments would imply positive values for politically active constituencies.[17]

We can now derive the optimal tariff analog to (11), for country $i$'s bilateral, politically motivated tariff in sector $x$ against trading partner $j$. The assumption of segmented markets makes work easy, as the only prices affected by a change in $\tau^i_{xj}$ are $p^i_x$ and $p^j_x$.

$$t^i_{xj} = \frac{1}{\hat{\epsilon}^i_{xj}}\left(1 + \overbrace{\frac{\delta^i_x q^i_x}{|\lambda_{xj}|M^i_{xj}}}^{\text{dom. prot. (+)}} - \overbrace{(1+\delta^*_{xi})\frac{\Delta\psi^j_{xi}}{M^i_{xj}}}^{\text{dom. va. abroad (-)}} - \overbrace{(1-\delta^i_{x*})\frac{\Delta\psi^i_{x*}}{|\lambda_{xj}|M^i_{xj}}}^{\text{for. va. at home (+/-)}}\right). \tag{17}$$

where $\lambda_{xj} \equiv \frac{dp^j_x}{d\tau}/\frac{dp^i_x}{d\tau} < 0$, $\hat{\epsilon}^i_{xj}$ represents the bilateral (sector specific) trade elasticity, and $M^i_{xj}$ denotes $i$'s imports of final goods in sector $x$ from country $j$.

The optimal tariff expression differs from the 2x2 case in three important ways. First, under the partial equilibrium assumptions, all variables are sector specific; there are no cross-sector general equilibrium effects. Second, in the bilateral setting, the effect of domestic value added embodied in foreign production now enters bilaterally via $\Delta\psi^j_{xi}$. This makes sense: when markets are segmented, a change in country $i$'s tariff against country $j$ affects prices in only countries $i$ and $j$, and thus only the returns to domestic value added embodied in foreign production in country $j$. In contrast, the effect of foreign value added embodied in domestic production, $\Delta\psi^*_{xi}$ remains multilateral. This is because the change in country $i$'s local price of $x$ is passed on to *all* foreign value added embodied in domestic production, not just the value added component derived from country $j$.

The third and final difference relative to the benchmark 2x2 optimal expression is the introduction of the political economy weights. A new term in the optimal tariff expression represents the political power of the import competing domestic producers of good $x$. The greater the political power of this group relative to social welfare (i.e. higher $\delta^i_x$), the higher the tariff, as in any 'protection for sale' model [Grossman and Helpman (1994)]. The political

[16] Under quasi-linear preferences, utilitarian social welfare is the sum of income and consumer surplus ($\zeta_s(p^i_s) \equiv [u_s(d_s(p^i_s)) - p^i_s d_s(p^i_s)]$); thus: $W^i = 1 + \sum_{s\in\mathcal{S}}[\pi^i_s(p^i_s) + R^i_s(\vec{p_s}) + \zeta_s(p^i_s) - \psi^i_{s*}(p^i_s) + \psi^*_{si}(\vec{p^*_s})]$ where $R^i_s(p_s)$ denotes tariff revenue from imports of good $s$.

[17] Standard 'protection for sale' lobbying would imply $\delta^i_s > 0$. $\delta^*_{si}$ would be positive if domestic value added exporters have a powerful political voice. If the government affords some consideration to the foreign value added components in domestic production, either to reflect "political goodwill" for tariff jumping foreign investors per Bhagwati, Brecher, Dinopoulos, and Srinivasan (1987), or because of lobbying contributions by foreign firms, as in Gawande, Krishna, and Robbins (2006), then $\delta^i_{s*} > 0$. While we have implicitly assumed that the home government affords zero consideration to foreign owners of value added embodied in foreign production, this assumption could easily be relaxed.

economy weights afforded to the claimants of traded value added enter the tariff expression multiplicatively, but with *opposite* signs. Adding political economy or lobbying motivations strengthens the potential tariff liberalizing influence of home's value added embodied in foreign production, $\delta^*_{xi}$, relative to the apolitical case. Conversely, affording a political voice to the foreign claimants of foreign-sourced value added embodied in domestic production would mitigate or even reverse (if $\delta^i_{x*} > 1$) the tariff liberalizing effect of foreign value added embodied in domestic production that arises in the absence of political motives.

Finally, notice that both the domestic political economy and value added terms are countered by the bilateral trade volume, $M^i_{xj}$, which reflects the standard (bilateral) terms of trade cost-shifting motive. Starting from the standard optimal (inverse-elasticity) tariff rule, the opportunity cost of a marginal reduction of the tariff is forgone tariff revenue. The greater the import volume, the greater the opportunity cost of liberalization, and hence the smaller the impact of the domestic political economy or value added terms on $t^i_{xjt}$.

## 1.3 Linking Optimal Tariffs to Value Added Content

In a final theoretical step, we decompose the two value added terms in (17) into elasticities and empirically quantifiable measures as follows:

$$\frac{\Delta\psi^j_{xi}}{M^i_{xj}} = \frac{1}{M^i_{xj}}\left(\frac{dr^j_{xi}}{dp^j_x}\nu^j_{xi}\right) = \frac{r^j_{xi}\nu^j_{xi}}{p^j_x M^i_{xj}}\left(\frac{dr^j_{xi}}{dp^j_x}\frac{p^j_x}{r^j_{xi}}\right) = \frac{r^j_{xi}\nu^j_{xi}}{p^j_x M^i_{xj}}\varepsilon^{rj}_{xi}, \tag{18}$$

$$\frac{\Delta\psi^i_*}{M^i_{xj}} = \sum_{c\neq i}\left[\frac{r^i_{xc}\nu^i_{xc}}{p^i_x M^i_{xj}}\left(\frac{dr^i_{xc}}{dp^i_x}\frac{p^i_x}{r^i_{xc}}\right)\right] = \varepsilon^{ri}_{x*}\sum_{c\neq i}\frac{r^i_{xc}\nu^i_{xc}}{p^i_x M^i_{xj}} \equiv \frac{r^i_{x*}\nu^i_{x*}}{p^i_x M^i_{xj}}\varepsilon^{ri}_{x*}. \tag{19}$$

The terms $\varepsilon^{rj}_{xc}$ describe the elasticity of the return to country $c$'s value added embodied in production of $x$ in $j$ with respect to changes in the local price of final goods in sector $x$ in country $j$. In (18), this elasticity captures the change in the returns to country $i$'s value added embodied in final goods production in sector $x$ in country $j$. In (19), we make the additional assumption that the elasticity terms are the same across all foreign value added components embodied in domestic production, so that the effect of foreign value added embodied in domestic production can be written in aggregate terms, using $^*$s to denote aggregates over all $c \neq i$. This simplification proves useful when we turn to the data.

Substituting (18) and (19) into the optimal bilateral tariff expression yields:

$$t^i_{xj} = \frac{1}{\hat{\epsilon}^i_{xj}}\left(1 + \frac{\delta^i_x q^i_x}{|\lambda_{xj}|M^i_{xj}} - (1+\delta^*_{xi})\varepsilon^{rj}_{xi}\frac{r^j_{xi}\nu^j_{xi}}{p^j_x M^i_{xj}} - \frac{(1-\delta^i_{x*})\varepsilon^{ri}_{x*}}{|\lambda_{xj}|}\frac{r^i_{x*}\nu^i_{x*}}{p^i_x M^i_{xj}}\right). \tag{20}$$

The value-added elasticities $\varepsilon_{xi}^{rj}$ and $\varepsilon_{x*}^{ri}$ map the effect of changes in final goods prices to changes in the returns to value added, and thus play a central role in determining the effect of value added trade on optimal tariffs. When the elasticities are higher, changes in the tariff will be passed through to the the real returns to value added, and thus national income. Ergo, higher elasticities translate to a stronger effect of trade in value added on optimal tariffs. In contrast, when these elasticities are low, less of the effect of a change in local final goods prices is passed through to the returns on value added; commensurately, trade in value added trade will have a smaller influence on optimal tariffs. In general, the pass through from local prices to the returns to value added will depend on production structure, contracts (e.g. bilateral bargaining), market power, etc. In the empirics, our coefficient estimates will capture in part these elasticities.

# 2 Empirical Strategy

We confront several challenges in taking the theory, summarized by Equation (20), to data. First, we do not directly observe some important determinants of optimal tariffs, including the export supply elasticities and the political economy weights. Second, while the closed form for tariffs in Equation (20) is useful for understanding the basic tradeoffs governments face, it is a product of a specific theory of tariff setting. This theory adopts functional form assumptions and requires governments to be perfectly informed about the underlying parameters (elasticites, value added contents, etc.). Third, institutional constraints limit the extent to which observed bilateral tariffs conform to the logic embodied in Equation (20). Most important are GATT/WTO rules that limit governments' discretion in setting unilateral bilateral tariffs.

For these reasons, care is needed in translating Equation (20) into an estimation framework. We break the work down in several steps. First, we focus on identifying and analyzing the role of domestic value added in foreign production in tariff setting. We then turn to an alternative set of specifications that allow us to estimate foreign value added effects as well. Finally, we adapt our approach to examine temporary trade barriers. In this section, we present the estimation strategy for tariffs in detail, and defer discussion of TTBs until we examine them below.

## 2.1 Optimal Bilateral Tariffs

The theory informs both the predictions we look for in the data and our identification strategy. The value-added augmented optimal tariff theory yields one clear sign prediction

to test: higher domestic value added in foreign final goods production should be associated with lower bilateral applied tariffs. The theory also suggests that applied bilateral tariffs should respond to the amount of foreign value added in domestic production. The prediction for the sign of this relationship is ambiguous, however, as it depends on the importance of political economy motives. Thus, we do not 'test' a specific prediction regarding the response of bilateral tariffs to foreign value added, but rather focus on signing the net effect empirically.

The theory provides two additional results that inform our empirical design. First, it suggests that the response of bilateral applied tariffs to value added contents may be heterogeneous across sectors and/or country pairs, and in particular that the responsiveness of bilateral tariffs to value added should be inversely related to the volume of final goods imports. We will exploit this heterogeneity in our approach to identify the impact of foreign value added in particular. Second, the theory emphasizes the importance of two well understood determinants of optimal tariffs: export supply elasticities and domestic political economy considerations. We tailor our selection of fixed effects and controls to capture these potentially confounding effects.

We present the estimation framework in two parts. The first part focuses on pinning down how domestic value added in foreign production influences bilateral tariffs. The second part examines the role of foreign value added as well.

### 2.1.1 Domestic Value Added in Foreign Production

We begin by restricting attention to domestic value added for three reasons. First, the theory makes a clear sign prediction, so we can focus our discussion around testing the theory. Second, we can implement tests for the sign prediction in a flexible framework, relaxing the exact functional form in Equation (20). Finally, from an economic perspective, domestic value added in foreign production lowers tariffs because it attenuates incentives for terms of trade manipulation. Given that terms of trade manipulation is the cornerstone of existing theoretical and empirical trade policy analysis, this is a natural place to start.

To make our notation conform more closely to verbal variable descriptions, we now define $DVA^j_{xit}$ to be the amount of domestic value added from country $i$ used by country $j$ in production of final goods in industry $x$, corresponding to $r^j_{xit}\nu^j_{xit}$ in the theory. Similarly, we define $FVA^i_{xt}$ to be the amount of foreign value added embodied in final goods produced by country $i$ in industry $x$, corresponding to $r^i_{x*}\nu^i_{x*}$. Further, in what follows we treat $\varepsilon^{rj}_{xi}, \varepsilon^{ri}_{x*}$, and $\epsilon^{ji}_x$, and $\lambda^i_x$ as constant parameters that will be absorbed in our coefficient estimates.

With these preliminaries, the optimal bilateral tariff can be rewritten as:

$$t^{i,opt}_{xjt} = \frac{1}{\hat{\epsilon}^{i}_{xj}} + \frac{\delta^{i}_{x} p^{i}_{xt} q^{i}_{xt} - (1-\delta^{i}_{x*})\varepsilon^{ri}_{x*} FVA^{i}_{xt}}{\hat{\epsilon}^{i}_{xj}|\lambda_{xj}|p^{i}_{xt} M^{i}_{xjt}} - \beta_{ijxt} DVA^{j}_{xit}, \tag{21}$$

where $\beta_{ijxt} \equiv \frac{(1+\delta^{*}_{xi})\varepsilon^{rj}_{xi}}{\hat{\epsilon}^{i}_{xj} p^{j}_{xt} M^{i}_{xjt}}$. This expression highlights three concerns that we need to address to estimate the causal impact of $DVA^{j}_{xit}$ on $t^{i}_{xjt}$.

The first is that we need to control for inverse export supply elasticities. As is well known, these are difficult to estimate, and particularly so in our bilateral context where we would need bilateral, sector-level export supply elasticities $\epsilon^{ji}_{x}$. Following the literature, we proceed by placing empirical restrictions on export supply elasticities. As a starting point, Broda, Limão, and Weinstein (2008) and Ludema and Mayda (2013) assume that export supply elasticities vary by importer and industry, but are identical across partners and through time, so that $\epsilon^{ji}_{x} = \epsilon^{i}_{x}$. Under this assumption, importer-industry fixed effects would absorb the inverse export supply elasticities. We relax this assumption, and include importer-industry-year and exporter-industry-year fixed effects in all specifications to control for variation in export supply elasticities.[18]

The second concern is that we need to control for political economy and foreign value added effects on tariffs, embodied in the second term of Equation (21). This term includes both the direct effect of foreign value added in lowering tariffs, as well as the political influence of (domestic and foreign) claimants to domestic final goods rents. The important point to note is that this term has a component that is specific to each importer, industry, and year (via $p^{i}_{xt} q^{i}_{xt}$ and $FVA^{i}_{xt}$), and a component that is bilateral and time-varying (via bilateral imports). To focus on the role of $DVA^{j}_{xit}$, we initially take a flexible approach to controlling for these confounding effects, and defer a more structural approach until we turn to estimating the influence of $FVA^{i}_{xt}$ on tariffs below. Recalling that we already include an importer-industry-year fixed effect to control for trade elasticities, we the interact these fixed effects with indicators for each quantile of the distribution of bilateral imports to form a collection of importer-industry-year-quantile fixed effects that absorb the influence of political economy and foreign value added on tariffs.[19]

The third concern is the potential for coefficient heterogeneity our estimated effects of $DVA^{j}_{xit}$. Empirically, the most important source of coefficient heterogeneity is heterogeneity

[18] In specifications with auxiliary bilateral observables (such regional trade agreement indicators), these controls partly absorb any residual variation in bilateral inverse export supply elasticities.

[19] For transparency, we first present results with simple importer-industry-year fixed effects, and then results for separate importer-industry-year by decile of bilateral imports. Comparing the estimates across these specifications sheds light on the importance of controlling for the bilateral component of variation in these confounding effects in identifying domestic value added effects.

in bilateral import volumes, which appear in the denominator of $\beta_{ijxt}$. In our benchmark specifications, we take a convenient transformation of the data that enables us to estimate a single (homogenous) coefficient, while respecting the economics underlying the latent coefficient heterogeneity. In particular, we adopt a semi-log specification in which we regress tariffs on $\ln(DVA^j_{xit})$. This specification is attractive because $DVA^{ij}_{xt}$ and bilateral final goods imports are strongly positively correlated in the data, with a raw correlation of about 0.72. Because $\beta_{ijxt}$ is inversely related to the level of bilateral final goods imports, we would therefore expect that a \$1 change in $DVA^j_{xit}$ at low levels of $DVA^j_{xit}$ should be more influential than a \$1 change in $DVA^j_{xit}$ at high levels of $DVA^j_{xit}$. The log function is a convenient transformation of the data that captures this mechanism, and thus implies that the coefficient attached to $\ln(DVA^j_{xit})$ should be stable throughout the data.

Based on this discussion, the core specification can be written as:

$$t^{i,opt}_{xjt} = \Phi_{xijt} + \beta \ln(DVA^j_{xit}) + e_{xijt}, \tag{22}$$

where $\Phi_{xijt}$ denotes the set of importer-industry-year-quantile and exporter-industry-year fixed effects discussed above. Further, note that we have re-written the coefficient on $\ln(DVA^j_{xit})$, so the sign prediction is $\beta < 0$. After we have the main results in hand, we relax the homogeneous $\beta$ assumption to examine coefficient heterogeneity across sectors and trading partners.

Before continuing, we highlight one additional concern. While our assumptions in the (bilateral) theory suppressed the possible endogeneity of value-added content for tractability, in practice, $DVA^j_{xit}$ could respond endogenously to final goods tariffs. Specifically, country $i$'s domestic value added embodied in production of final goods in sector $x$ in trading partner $j$ may be decreasing in country $i$'s tariff against imports of $x$ from $j$. If true, this mechanism would induce a negative correlation between $\ln(DVA^j_{xit})$ and $e_{ijxt}$.[20] We account for this possibility using an instrumental variables strategy. We defer discussion of the specifics of the instrument until later in the section.

### 2.1.2 Foreign Value Added in Domestic Production

Because we use only variation within industry-sector-year as a source of identification, we need to use additional structure provided by the theory in order to estimate how tariffs vary

[20]Note that $DVA^j_{xit}$ is total value added, not value added per unit of the final good. Given a pre-existing input supply relationship between $i$ and $j$, $DVA^j_{xit}$ could rise mechanically if lower tariffs induce higher final goods imports, and hence more upstream demand for inputs from home. Lower tariffs might also give rise to new input supply relationships. For example, a lower final goods tariff applied to country $j$ in sector $x$ could induce domestic firms to offshore final production stages to country $j$ for sector $x$, thereby raising $DVA^j_{xit}$.

with $FVA^i_{xt}$. Returning to the optimal bilateral tariff expression, we re-write it here as:

$$t^{i,opt}_{xjt} = \frac{1}{\hat{\epsilon}^i_{xj}} + \gamma^{DPE}_{ijx}\left(\frac{p^i_{xt}q^i_{xt}}{p^i_{xt}M^i_{xjt}}\right) - \gamma^{FVA}_{ijx}\left(\frac{FVA^i_{xt}}{p^i_{xt}M^i_{xjt}}\right) - \gamma^{DVA}_{ijxt}\left(\frac{DVA^j_{xi}}{p^j_{xt}M^i_{xjt}}\right), \tag{23}$$

where $\gamma^{DPE}_{ijx} \equiv \frac{\delta^i_x}{\hat{\epsilon}^i_{xj}|\lambda_{xj}|}$, $\gamma^{FVA}_{ijx} \equiv \frac{(1-\delta^i_{x*})\varepsilon^{ri}_{x*}}{\hat{\epsilon}^i_{xj}|\lambda_{xj}|}$, and $\gamma^{DVA}_{ijx} \equiv \frac{(1+\delta^*_{xi})\varepsilon^{rj}_{xi}}{\hat{\epsilon}^i_{xj}}$.

Relative to Equation (21), we split the domestic political economy and foreign value added terms, and we collect imports with other observables to form three ratios. These are the ratios of (respectively) domestic final goods production, foreign value added, and domestic value added, relative to bilateral final goods imports. These ratios recognize bilateral variation in the strength of each force in shaping tariffs, due to government trading tariff revenue (which depends on bilateral imports) off against other concerns, as discussed in Section 1.2. Because these predictions derive from the optimal tariff calculus, the empirical specifications based on them rely more heavily on the theory than those in the previous section. The obvious payoff is that we can separate channels that we could not identify in the more flexible specifications above. Moreover, since this approach also yields estimates for the influence of DVA on tariffs, which we can uses these more structural estimates as a check on the results obtained under the more flexible strategy of Section 2.1.1.

We construct the three ratios in our data, which we refer to as the inverse import penetration ratio, the DVA-ratio, and the FVA-ratio for short. Following the discussion above, we impose homogeneous coefficients in our main regressions, and therefore estimate the sample average partial derivatives of tariffs with respect to each ratio. We again include importer-industry-year and exporter-industry-year fixed effects to absorb unobserved inverse trade elasticities. The main empirical specification is:

$$t^{i,opt}_{xjt} = \Phi_{ixt} + \Phi_{jxt} + \gamma^{DPE}\left(\frac{p^i_{xt}q^i_{xt}}{IM^i_{xjt}}\right) + \gamma^{DVA}\left(\frac{DVA^j_{xi}}{IM^i_{xjt}}\right) + \gamma^{FVA}\left(\frac{FVA^i_{xt}}{IM^i_{xjt}}\right) + u_{ijxt}. \tag{24}$$

where $\Phi_{ixt}$ and $\Phi_{jxt}$ denote the set of importer-industry-year and exporter-industry-year fixed effects and $IM^i_{xjt}$ is the value of bilateral final goods imports.[21] As above, note we have re-written the coefficients so the sign predictions are $\gamma^{DPE} > 0$, $\gamma^{DVA} < 0$; as noted earlier, $\gamma^{FVA} \lessgtr 0$ depending on the political strength of foreign value-added.[22]

[21] A subtle point is that imports are evaluated at exporter prices when compared to $DVA^j_{xi}$, and evaluated at importer prices in the other two ratios. We currently suppress this distinction in our empirical work.

[22] As we discuss further below, we consider two different specifications, one with the ratios and one with log ratios on the right hand side. The log specification addresses a particular type of measurement error that arises from measurement error in imports, but cannot (by mathematical identity) separately identify $\gamma^{DPE}$ and $\gamma^{FVA}$; instead, it delivers an estimate of their joint influence.

New endogeneity concerns arise in this empirical specification. In principle, the levels of domestic production, imports, and foreign value added - and hence the ratios on the right hand side - may be correlated with the residual variation in tariffs. For example, one would expect imports to be lower when residual tariffs (captured in $u_{ijxt}$) are higher. Moreover, foreign value added may depend on tariffs, as high final goods tariffs could induce tariff jumping, whereby foreign firms conduct final production stages locally with imported inputs. For these reasons, we again instrument for the ratios on the right hand side, and again defer discussion of instrument construction until we arrive at those estimates.

### 2.1.3 A Note on Interpretation: Tariffs Levels vs. Tariff Preferences

Before proceeding, we would like to emphasize one final important point of interpretation that applies to all our of ordinary least squares results based on Equations (22) and (24). In all specifications, we include importer-industry-year (or more restrictive) fixed effects. These fixed effects absorb all variation in multilateral, industry-level tariffs in the data, and so we identify the role of DVA and FVA on tariffs by looking only at differences between applied bilateral tariffs and multilateral applied tariffs. Put differently, if we define the dependent variable to be the difference between bilateral optimal tariffs and the country's applied MFN tariff ($t^{i,opt}_{xjt} - t^{i,MFN}_{xt}$), instead of tariff levels ($t^{i,opt}_{xjt}$), then we obtain identical OLS coefficient estimates.[23] To explain why this is an important component of our identification strategy, we now turn to a discussion about the relationship between *optimal* (unconstrained) bilateral tariffs and *observed* bilateral tariffs.

## 2.2 Optimal vs. Observed Tariffs: Trade Policy Institutions

Thus far, we have described strategies for estimating the influence of value-added content on optimal bilateral tariffs. In practice, we do not observe optimal bilateral tariffs for all country pairs and industries in our data, because countries set bilateral tariffs subject to various institutional constraints. The most obvious constraint is the "most-favored-nation" (MFN) rule, articulated in Article I of the GATT, which limits the ability of countries to discriminate among their trading partners. One important implication of the MFN rule is that countries are not allowed to set bilateral tariffs above their applied MFN tariff rate for other WTO members with 'normal trade relations'.[24] Despite the spirit of MFN, countries

[23]Regarding notation, let $t^{i,MFN}_{xt}$ be country $i$'s MFN tariff in sector $x$ at time $t$.

[24]Our 14 country sample includes primarily WTO members. The exceptions are China and Taiwan in 1995 and 2000, and Russia throughout our sample period. While it is possible value-added motives shape negotiated MFN tariffs, we do not model this explicitly. Whether negotiated MFN tariffs would depend on value-added contents depends on whether terms-of-trade effects are fully internalized in WTO negotiations,

can and do apply lower-than-MFN tariffs to particular trading partners under a number of exceptions to the MFN rule (including Article XXIV and the Enabling Clause). As such, the MFN tariff rate represents a hard upper bound on bilateral tariffs, but is only a weak constraint in lowering bilateral tariffs.

Recognizing this institutional context, we model observed bilateral tariffs as follows. When we observe bilateral tariffs for country $i$ against $j$ below the applied MFN tariff of country $i$ in sector $x$, then we assume the bilateral tariff is set based on optimal tariff considerations, according to Equations (22) and (24). When we observe bilateral tariffs set at the applied MFN rate, we assume that the optimal bilateral tariff is greater than or equal to the applied MFN tariff. To formalize, let $t_{xt}^{i,MFN}$ represent the applied MFN tariff of country $i$ in sector $x$ at time $t$. We assume that observed bilateral tariffs, denoted $t_{xjt}^{i}$, are given by:

$$t_{xjt}^{i} = \begin{cases} t_{xjt}^{i,opt} & \text{if} \quad t_{xjt}^{i,opt} < t_{xt}^{i,MFN}, \\ t_{xt}^{i,MFN} & \text{otherwise.} \end{cases} \tag{25}$$

Put simply, the MFN constraint censors observed optimal bilateral tariffs. As is standard, if we ignore this censoring, we will tend to underestimate the influence of value added contents on bilateral tariffs. For example, for countries and sectors where applied MFN rates are low ($t_{xt}^{i,MFN} \to 0$), then we will observe variation in value added contents across partners, but will observe little variation in observed bilateral tariffs ($t_{xjt}^{i}$). More generally, optimal tariffs against source countries that use relatively little domestic value added in production are more likely to hit the upper bound, so we will observe less variation in applied tariffs than the optimal tariff theory would suggest. For these reasons, we present results both without and with corrections for censoring-from-above.

In addition to this MFN-censoring, tariffs are also generally non-negative.[25] Recognizing this, we also present results with corrections for two-sided censoring. Due to the small number of zero tariffs in our data, this correction proves to be less important empirically than dealing with the MFN-censoring discussed above.[26]

One final important concern is that some tariffs are set via bilateral or regional trade agreements (free trade agreements or customs unions), which we henceforth refer to as RTAs for short. Bilateral tariff preferences arising under these agreements are set via bilateral

as Ludema and Mayda (2013)emphasize. We set aside the study of MFN tariffs for future work.

[25]In principle, countries can set negative tariffs by subsidizing imports, but we do not observe this in our aggregated data.

[26]While there are 1085 zero tariffs in our data (out of 10,740 bilateral tariffs, about 10% of the sample), 440 of these occur for importer-exporter-industry-year cells where the applied MFN tariff is also zero and thus play no role in our empirical results. The remaining 645 zero tariffs constitute roughly 6% of the sample, and are dwarfed by the number of observations where bilateral tariffs are at the MFN ceiling, which account for over half of our data as we describe below.

negotiation, in contrast to other unilateral preferences in our data. To the extent that these negotiations allow RTA-partners to neutralize terms of trade externalities among themselves, then bilateral tariff preferences secured within RTAs will not reflect terms-of-trade considerations. This would remove any influence of domestic content in foreign production on these bilateral tariffs.[27] Further, under WTO Article XXIV, adoption of regional agreements requires in principle that countries move tariffs to zero on "substantially all trade." If RTA agreements adhere to this principle, this further constrains tariffs set within RTAs and obscures the influence of terms-of-trade motives.

While these institutional observations suggests we should treat bilateral tariff preferences arising from RTAs with care, there are several reasons to include preferences granted via RTAs in our analysis. First, observance of the "substantially all trade" rule is notoriously weak.[28] Many RTAs include substantial carve outs, where tariffs remain positive in important sectors, as we observe in our data. Further, RTAs among developing countries may be initiated under the WTO Enabling Clause (rather than Article XXIV), which exempts them from the "substantially all trade" requirement.[29] Finally, given that liberalization is incomplete within each RTA, and that countries engage in multiple RTAs with differential degrees of liberalization across partners, this suggests that they may contain useful variation for identifying the role of value added content on preferential tariff setting.

In light of these cross-cutting concerns, we deal with complications regarding RTAs as follows. We first present results including all RTA preferences, on equal footing with non-RTA preferences. By doing so, we recognize that countries may exercise discretion in trade policy via carve outs within RTAs. Second, we then add (time-varying) indicators for the existence of regional trade agreements among country pairs in all our specifications. This absorbs the bulk of variation in tariffs attributable to RTAs in our sample. Third, we perform additional robustness checks in which we use only variation in preferential tariffs set outside regional agreements. We discuss these exercises in more detail when we review the results.

[27]Since the role of foreign value added is not tied to terms-of-trade manipulation, then one might still see the influence of foreign value added in domestic production on these tariffs.

[28]As Estevadeordal, Freund, and Ornelas (2008) put it: "Article XXIV is ... perhaps the least enforced article of the GATT, and in reality the complete elimination of internal tariffs is the exception, rather than the rule, in most operative RTAs." For analysis of RTA coverage by the WTO Secretariat, see WTO (2011).

[29]For example, the Asia Pacific Trade Agreement covering China, South Korea, and India in our data (and other countries not in our data), was initiated under the Enabling Clause. Though the scope of this agreement has widened over time, it covered (and still covers) only a limited set of products. See United Nations ESCAP (2013).

# 3 Value-Added and Trade Policy Data

In this section, we summarize our data sources and measures of value added content and bilateral trade policy. We also introduce our data bilateral tariff preferences.

## 3.1 Value-Added Content

We use data from the World Input-Output Database (WIOD) to compute the national origin of value added contained in each country's final goods.[30] The WIOD contains a sequence of global input-output tables for the 1995-2009 period, which describe bilateral final and intermediate goods shipments for 35 industries across 27 EU countries and 13 other major countries.

Drawing on Los, Timmer, and de Vries (2014), we use these data decompose final goods as follows. Let $i, j \in \{1, 2, \ldots, N\}$ denote countries and $s \in \{1, 2, \ldots, S\}$ denote industries. Let $y_t$ by a $S \times N$ vector with $S$-dimensional elements $y_{it}$, the output vector for each country. Let $A_t$ denote the global input-output matrix, with $S \times S$-dimensional block elements $A_{ijt}$ that record inputs shipments from sector $s$ in country $i$ to sector $s'$ in country $j$ as a share of gross output in sector $s'$ in country $j$. Letting $f_{ijt}(s)$ denote final goods shipped from $i$ to $j$ in sector $s$ and $f_{it}(s) = \sum_j f_{ijt}(s)$ be total final goods produced in $i$. Then collect these into $S \times 1$ country vector $f_{it}$, and $SN \times 1$ world final goods vector $f_t$. Then, the global input-output system can be written as: $y = Ay + f$.

As is standard, the Leontief inverse of the global input-output matrix – $[I - A]^{-1}$ – times any $SN \times 1$ vector of final goods equals yields the $SN \times 1$ vector of gross output (from all countries and industries) required to produce those final goods.[31] Then, we can define: $Y_t \equiv [I - A_t]^{-1} diag(f_t)$. Breaking this down, $Y_t$ contains block elements $Y_{ijt}$ which are $N \times N$ matrices describing output from used (directly or indirectly) from $i$ to produce final goods in $j$. Each sub-component $Y_{ijt}(s, s')$ is the amount of output from industry $s$ used in producing output in industry $s'$.

These output requirements can be translated into value-added requirements if we know value-added to output ratios in each sector of source country $i$: $R_{it}(s)$. The total amount of value added from $i$ embodied in country $j$'s production in industry $s'$ is: $v^j_{sit} \equiv \sum_s R_{it}(s) Y_{ijt}(s, s')$.[32]

[30] The data is available at *http://www.wiod.org* and documented in Timmer (2012).

[31] Due to the way input-output data are compiled, we implicitly adopt the restriction here that sector-level production requirements are the same no matter where final goods are shipped. For example, a German car contains the same amount of French value added no matter whether it is shipped to Italy or Spain.

[32] In the WIOD data, $y = Ay + f$ holds when quantity shipments are translated into values using basic prices. To satisfy adding up constraints, we also construct value-added at basic prices, so $R_{it}(s)$ is gross output at basic prices less the value of inputs used at basic prices, divided by output at basic prices. This differs from GDP accounting conventions, where value added is output at basic prices less the value of inputs

We use these value added contents to construct proxies for domestic value added in foreign production in $j$ ($r^j_{sit}v^j_{sit}$) and foreign value added in domestic production ($r^i_{s*}v^i_{s*}$). Specifically, we use $v^j_{sit}$ as a measure of $r^j_{sit}v^j_{sit}$, and use $v^i_{s*t} \equiv \sum_{j \neq i} v^i_{sjt}$ as a measure of $r^i_{s*t}v^i_{s*t}$.

We construct these variables for all countries and sectors in the data, and then retain values for 14 "countries" (13 non-EU countries, plus the composite EU region) and 15 goods producing sectors (13 manufacturing sectors, plus agriculture and food, beverages, and tobacco).[33] The countries and sectors are listed in Table 1. In our empirical analysis, we focus on four years: 1995, 2000, 2005, and 2009.

## 3.2 Tariffs

We need data on bilateral, industry-level tariffs on final goods for the set of countries and industries in Table 1 for 1995, 2000, 2005, and 2009. We construct these tariff measures using national government, product-level tariff schedules. The raw data are collected and formatted by UNCTAD (TRAINS) and the WTO, and made available through the World Bank's WITS (World Integrated Trade Solution) website.[34] In the analysis, we use data on multilateral most-favored-nation (MFN) applied tariffs, MFN tariff binding commitments, and bilateral applied tariffs.

The WTO provides product-level MFN applied tariffs and tariff bindings for member countries. The MFN applied tariff is the tariff that one WTO member applies to imports from other WTO members, unless the particular partner is granted a tariff preference. The MFN binding commitment is the level above which the country has committed not to raise the tariff it applies toward any other WTO member.

The TRAINS data contains bilateral applied tariffs. These tariffs differ from the MFN applied tariff for two reasons. First, WTO members offer preferential (lower-than-applied MFN) tariffs to selected partners under various preference schemes. These include reciprocal free trade agreements (e.g., the North American Free Trade Agreement) and customs unions (e.g., between the European Union and Turkey). They also include unilateral preference schemes, such as the Generalized System of Preferences under which developing countries receive preferential treatment from high income importers.[35] Finally, product-specific agree-

at purchaser's prices.

[33] We first compute value-added contents using the full 40 country data set, and then aggregate ex post to form the EU composite. We aggregate the EU because they have common external tariffs and trade policy.

[34] See *http://wits.worldbank.org*.

[35] Despite the 'generalized' moniker, preferences granted under the GSP program are discretionary. In particular, importers unilaterally select specific countries and products to receive concessions under the program. See Blanchard and Hakobyan (2014) for detailed analysis of the US GSP program.

ments and one-off unilateral programs are a final source of preferences.[36]

Second, several countries in our sample are not WTO members (Russia for the entire sample, and China and Taiwan before their WTO accessions in 2001 and 2002, respectively). Therefore, WTO members did not necessarily need to extend MFN treatment to exports from these countries.[37] Moreover, tariffs on imports by these countries were not constrained by the WTO, nor included in their data. Therefore, all import tariff information for these countries during their pre-accession years is taken from TRAINS.

While these databases contain a wealth of data, there are a number of challenges in turning these into usable data. First, there are a handful of instances in which a country's entire bilateral tariff schedule is missing in one of our four benchmark years. In these cases, we take the tariff schedule from the closest available year for that country. Second, tariff lines (products) are not defined consistently across countries at the most disaggregate level. We therefore take the unweighted mean across product lines within HS 6-digit Harmonized System (HS-06) categories, which are standardized across countries. Third, there are cases where tariffs are mis-recorded, or entirely missing, for a sub-set of products or partners in any given year. In some cases, we are able to resolve these idiosyncratic problems via inspection.[38] In others, this results in missing data, covering about 2% of the possible importer-exporter-industry-year units in our data.[39]

With the set of HS-06 bilateral applied tariffs, we use the Broad Economic Categories (BEC) classification to identify final goods categories. We then concord the HS-06 tariffs for final goods to their World Input-Output Database (WIOD) industry codes in order to construct a simple average, industry-level, bilaterally applied import tariff. For these industries, we rely on the same methodological approach to construct the associated MFN applied import tariff rate and the MFN binding rate.

[36] As an example of one-off preferences, Australia offered Canada a preference for "Adhesive dressings for medical purposes" under its national tariff line 30051000 in the year 2000.

[37] In some instances, we see WTO members applying higher-than-applied-MFN tariffs toward non-WTO partners. All our results below are robust to taking these at face value, or simply replacing these observations with MFN applied rates.

[38] For example, a country's data may omit a particular tariff preferences program in a given year, even though that program exists in the country's data in the years prior and subsequent to the missing year. While it is possible that such programs may have been temporarily suspended, our investigative efforts to validate such potential temporary suspensions typically uncovered no corroborating evidence of a genuine change in policy. Therefore, we use information on preferences from surrounding years.

[39] For example, when a country's particular tariff is applied as a specific duty, the estimated ad valorem equivalent may be missing.

## 3.3 Temporary Trade Barriers

We obtain data on temporary trade barriers (TTBs) of antidumping, safeguards, and countervailing duties from the World Bank's Temporary Trade Barriers Database [Bown (2014)]. These data include information on the importer, the country against which the TTB is imposed, the product-line (defined by the importer), and the timing of when policies are imposed and removed.[40]

Some TTBs are applied as ad valorem duties, but others are applied as specific duties, price undertakings, or quantitative restrictions. Rather than attempting to convert these into ad valorem equivalents , we construct import coverage ratios to track TTB use over time.[41] In particular, we construct import coverage ratios for the stock of accumulated TTBs that a policy-imposing country has in effect against a particular trading partner in a given industry at a particular point in time, following the approach described in Bown (2011). As in the construction of the tariff data, we begin with TTB application data at the product-level, then aggregate up to the HS-06 level, extract HS-06 categories corresponding to final goods using the BEC classification, and then aggregate to WIOD industries. Our measure of TTB import protection is the simple average share of HS-06 final goods products within a WIOD sector for which the policy-imposing country has a TTB in effect against a particular trading partner. We construct these measures for each of the years in our sample (1995, 2000, 2005, and 2009), which allows for both the imposition of new TTBs and removal of existing TTBs over time.

## 3.4 A First Peek at the Tariff Data

Before moving to formal analysis, we pause here to introduce the tariff data. We start by reviewing a few salient facts about bilateral tariff preferences, and then relate this variation to value added content in an illustrative case. The unit of observation in the analysis will be the tariff for importer $i$ against exporter $j$ in industry $s$ at year $t$. With 14 countries, 15 industries, and 4 years, this gives us $10,920$ ($14 \times 13 \times 15 \times 4$) potential observations. Our actual baseline sample consists of $10,803$ observations, due to missing or problematic data on tariffs or value added contents in a some instances.

**Tariff Preferences** Our identification strategy exploits differences between bilateral applied tariffs and applied MFN rates. In our data, there is significant variation in tariff

[40] The data cover all importing countries in our sample, except for Russia. Due to our focus on production of final goods, we also exclude China and Taiwan in our analysis of TTBs, because nearly all their TTBs are imposed on intermediate inputs.

[41] Our use of NTB coverage ratios follows Trefler (1993) and Goldberg and Maggi (1999), among others.

preferences across country pairs and sectors, which is the foundation on which the rest of the empirical work rests. Exporters receive preferential treatment in about one-third of our observations. Conditional on receiving preferences, the median difference between the applied bilateral tariff and the applied MFN tariff is about $-2.4$ percentage points, with a 10th-90th percentile range of $[-8.27, -0.14]$.[42] We plot the distribution of preferences in Figure 1.

We tabulate observations where we observe preferences along two dimensions in Table 2, by preference program and direction of trade. We look first at preferences by program, distinguishing regional trade agreements, preferential trade agreements, and the generalized system of preferences using the coding of bilateral agreements by Baier and Bergstrand (2014). In a minority of cases (18%), preferences are extended under formal regional trade agreements (free trade agreements or customs unions). The majority (82%) of preferences are extended outside of full RTAs. Roughly 9% of preferences are granted among country pairs with preferential trade agreements (weaker than full free trade agreements), and 44% are granted among country pairs in which the high income partner extends GSP privileges to its low income partner. The remaining 29% of preferences fall under the auspices of other programs.

Turning to preferences by direction of trade, we would like to highlight a few facts about who gives and who receives preferences in our data. We focus in particular on distinguishing high income vs. emerging markets exporters and importers, respectively. The bulk of preferences in our data (55%) are extended by high income countries to emerging markets. This is consistent with the prevalence of GSP preferences in the data. Nonetheless, emerging markets are also active in extending preferences, accounting for 31% of preferences, with 2/3 of those preferences granted to other emerging markets.

One additional salient feature of the data is that the scope for preferences is obviously constrained by MFN. In sectors with low average MFN rates, the absolute value of the mean preference is lower, and the standard deviation of preferences is higher. For reference, we plot the mean preference and standard deviation of preferences versus average MFN tariffs by sector in Figure 2. Interestingly, MFN rates are not obviously important constraints on the value of preferences across importing countries. The reason is that emerging markets, which have high average MFN tariffs, tend to extend fewer preferences than do high income countries, which have low average MFN tariffs.

**Tariff Preferences and Domestic Value Added** Before putting the pieces together formally, we want to introduce a simple illustrative scatter plot, both to illustrate variation

[42] Including observations with zero tariff preference, the unconditional median tariff preference is zero, and the 10th-90th percentile range is $[-3.76, 0]$.

in the data and motivate a number of concerns that we address in the empirical analysis that follows.

Figure 3 plots bilateral tariff concessions ($t^i_{xj} - t^{i,MFN}_x$) against bilateral domestic content in foreign production ($\ln(v)^j_{si}$) for the set of high income importers against emerging market exporters in 2005. The left panel focuses on the Textiles and Apparel industry, where both the scope for and use of discretion is high. The right panel depicts the same correlation for manufacturing as a whole, where the y-axis is the simple mean concession across all manufacturing industries and the x-axis is total domestic value added in foreign manufacturing.

Several points stand out in this figure. First, there is a clear negative correlation, which means importers seem to grant larger concessions to countries that use a lot of domestic (importer) value added in production of their final goods. Roughly speaking, this is the correlation we are estimating in the OLS results, where we start our formal analysis.

Second, there is an obvious censoring problem in the figure, as indicated by the mass point at zero concession.[43] The MFN rule constrains bilateral tariffs, even though countries might like to unilaterally raise against countries where they have low domestic value in foreign production (the left end of the x-axis). The inability to do so clearly biases down the correlation between domestic value added and optimal tariffs that we would infer from this data. This motivates our attention to censoring issues in our results below.

Third, eyeballing particular country pairs in the figure, it's evident that a number of observations in the lower right part of the figure are cases where the country pair has a regional trade agreement. This observation motivates our attention to demonstrating that regional trade agreements are not the only (or even most important) source of variation driving our results below.

Finally, we highlight observations where China is an exporter in the figure, as it is evident that China receives relatively few preferences despite the high foreign content of its exports. This is indicative of possible political economy (or other non-modeled) forces that lead particular exporters to receive fewer preferences than others. We will be cognizant of this as well in our estimates.

# 4 Results

We present results for bilateral tariffs first, then turn to complementary evidence for temporary trade barriers.

[43]The less obvious censoring problem is that there is also a lower mass point for tariff concessions, equal to the value of the MFN tariff for each importer.

## 4.1 Tariffs

The tariff results follow the structure outlined in Section 2. We open with results focusing on the influence of domestic value added in foreign production on bilateral applied tariffs, and then turn to an alternative specification to estimate the influence of foreign value added in domestic production.

**Domestic Value Added in Foreign Final Goods** Table 3 presents the benchmark OLS results. In columns (1) and (3), we present estimates using all the bilateral variation in tariffs, and in columns (2) and (4) we include binary indicators for the existence of bilateral/regional trade agreements. In all columns, we include exporter-industry-year fixed effects. We include importer-industry-year fixed effects in columns (1) and (2), and then adopt the more restrictive importer-industry-year-decile (of bilateral imports) fixed effects in columns (3) and (4).

The main result is that the coefficient on log domestic value added is negative in all columns, which indicates that higher domestic value added in foreign final goods production is associated with lower applied bilateral final goods tariffs. The estimated effect strongest when we use all tariff variation (including tariffs adopted under RTAs), and gets smaller when we control for RTAs (as expected).[44] Further, the point estimates are somewhat larger (in absolute value) in specifications with importer-industry-year fixed effects, and somewhat smaller with importer-industry-year-decile fixed effects. The estimates in column (4), which control for bilateral political economy, foreign value added effects, and regional trade agreements are our preferred specification.

To interpret the magnitudes, the point estimate in column (4) is $-0.41$. For a given importer and industry, it is typical for the independent variable $\ln(DVA^{j}_{xit})$ to vary by roughly 3 log points across bilateral partners. Thus, moving from low to high DVA partners yields a reduction of 1.2 percentage points in applied tariffs. Since the median tariff is 8 percent, this represents about a 15% reduction in the typical tariff level.

To unpack these results further, we next examine whether (and how) the role of domestic value added varies across industries, years, countries, and the direction of trade in Tables 4 and 5. In Table 4 we present separate coefficient estimates across agriculture and food industries, the textiles, apparel, and footwear industries, and other manufacturing industries. We find negative coefficients on domestic value added in all industry groups, and note that the coefficient is particularly large in the textiles, apparel, and footwear industries. One

[44] RTA partners have lower bilateral applied tariffs, approximately 5 percentage points lower than non-RTA pairs. In unreported results, we have explored alternative approaches to dealing with tariffs set via RTAs. The negative and significant coefficient on domestic value added is robust to either dropping all observations with RTAs, or replacing RTA tariffs with average or MFN tariffs.

plausible reason for this difference is that the scope for discretion is larger in this sector, because MFN tariffs are higher here than for the rest of manufacturing. We return to this point in discussing censoring corrections below. In the bottom panel of Table 4, we find negative coefficients on domestic value added in all sample years, with no obvious trend in these coefficients over time.

In Table 5, we present coefficients by importer income group, and by direction of trade. In the top panel, we see that the coefficient on domestic value added is somewhat larger (again, in absolute value) for emerging markets than high income countries. This is consistent with the idea that emerging markets have more scope for discretion, due to higher baseline MFN tariffs. In the bottom panel of Table 5, we allow the coefficients to vary by the direction of trade between high-income and emerging countries. We split the sample into high-to-high, high-to-emerging, emerging-to-high, and emerging-to-emerging trade flows. For high income importers, we find a negative coefficient for imports from emerging markets in column (5), with magnitude similar to the overall sample, but find a near zero (insignificant) coefficient for imports from other high income countries in column (4).

These results are consistent with the underlying institutional features of the world trade system. Therefore, they not only offer insight into the nature of tariff variation in our data, but also constitute a basic plausibility check for our findings. Under WTO rules, high income countries have limited ability to offer other high income countries preferences outside of free trade agreements. Thus, once we control for trade agreements, high income countries should have little residual scope to manipulate bilateral tariffs among themselves in response to value added contents. The null result for high income to high income trade flows confirms this. In contrast, high income countries retain flexibility to offer preferences to emerging market partners outside of free trade deals (under the Enabling Clause); and indeed, we find strong evidence of discretionary treatment of these trade flows. Likewise, emerging markets generally have more scope for discretion, and we find that they actively discriminate across both high income and emerging market partners in columns (6) and (7).

In sum, we find evidence that higher domestic value added in foreign final goods production is associated with lower bilateral applied tariffs. This result holds across sectors and years, for both high income and emerging market importers, and at the bilateral level where these exists scope for discretion (but not where discretion is limited among high income partners). Moreover, where we do observe heterogeneity in coefficient estimates, the patterns are broadly consistent with institutional begin features of the multilateral trading system.

Thus far, we have presented straight OLS estimates. We now turn to estimates that address possible endogeneity concerns and correct for censoring. As noted above, the direct

endogeneity concern we have is that domestic value added from $i$ used by $j$ in sector $x$ may be influenced by the tariffs that $i$ sets against $j$ in sector $x$. To address this possibility, we instrument for $DVA^i_{xjt}$ using the interaction between bilateral DVA in sectors other than sector $x$ and a sector-specific trend in the importance of offshoring sector $x$. Formally, we define $DVA^i_{(-x)jt} \equiv \sum_{x' \neq x} DVA^i_{x'jt}$ and $Industry_{(-i)(-j)xt} \equiv \frac{\sum_{k \neq i,j} \sum_{l \neq i,j} DVA^k_{xlt}}{\sum_x \sum_{k \neq i,j} \sum_{l \neq i,j} DVA^k_{xlt}}$. Then the instrument is given by: $DVAIV^i_{xjt} \equiv DVA^i_{(-x)jt} \times Industry_{(-i)(-j)xt}$. Note that the instrument omits all information pertaining to the use of domestic value added from $i$ by $j$ in sector $x$, as is necessary to break the mechanical endogeneity concern.

Instrumental variable results are presented in columns (1) and (2) of Table 6. The takeaway is that the OLS results from Table 3 not only hold up, but actually strengthen when when we instrument for domestic value added content. This suggests that the mechanical endogeneity concerns described above do not seem to be inflating our estimates, and if anything that countervailing concerns – such as measurement error – may be pushing the OLS results toward zero.

Turning to censoring, recall that bilateral tariffs are effectively censored, in that they may be set up to, but not above, the MFN level for WTO partners. We expect this to bias the OLS and Linear-IV results toward zero, since they describe how observed tariffs (including values at the upper MFN bound) rather than optimal tariffs respond to value added content. To examine the impact of MFN censoring, we implement one-sided and two-sided Tobit regressions in columns (3)-(6) of Table 6.[45] As expected, the coefficient on domestic value added rises (in absolute value), roughly tripling to $-1.20$ with a one-sided correction and $-1.28$ with a two-sided correction. Given the 'typical' 3 log point spread in domestic value added content across partners, this revised estimate implies that optimal tariffs are roughly 3.5-4 percentage points lower for partners with high relative to low domestic value added content. Allowing the coefficient to be heterogeneous across industry groups in columns (4) and (6), we note that the extent of attenuation induced by censoring is largest in manufacturing, where correcting for censoring raises the coefficient five fold.[46]

**Foreign Value Added in Domestic Final Goods** We now shift gears and specifications to identify the influence of foreign value added in domestic production on optimal tariffs. In particular, we shift to specifications based on Equation (24), in which ratios of final goods production, domestic value added, and foreign value added to bilateral imports appear separately on the right hand side.

[45] In these columns, we report estimates with importer-industry-year fixed effects. Results with the full set of importer-industry-year-decile controls are similar.

[46] The coefficient also rises in other industries, by roughly 3 times in Agriculture and Food, and roughly 2 times in Textiles, Apparel, and Footwear.

In implementing this specification, we confront a minor technical obstacle due to the presence of bilateral imports in the denominator. Small (often near zero) values of imports generate extreme ratios that muddy inference. Moreover, any measurement error in bilateral imports is necessarily inflated by the inverse functional form, leading to nonclassical measurement error in the ratios. We address this issue in several complementary ways, all of which involve taking monotone transformations of the ratios. First, we winsorize the ratios on the right hand size, performing a one-sided 5% winsorization. Second, we divide each ratio into 50 quantile bins, and replace the values of each ratio with the corresponding bin number. Third, we take logs of the ratios. This third approach implies that we cannot separately identify the role of the inverse import penetration ratio from the role of foreign value added in domestic final goods production. Thus, this last specification serves primarily as a robustness check on the previous two approaches.

The results of this estimation are presented in Table 7. All three approaches lead to similar results. As in the prior results, we find that higher domestic value added in foreign final goods is associated with lower bilateral applied tariffs.[47] The key new result is that higher foreign value added in domestic production – or more precisely, a higher ratio of foreign value added in domestic production to bilateral imports – is positively correlated with bilateral import tariffs. As discussed earlier, this finding is consistent with the idea that foreign value added receives substantial political weight in determining final goods tariffs. That is, upstream foreign political interests appear to receive weight in determining downstream final import tariffs.

This result is perhaps surprising at first blush, so it merits further discussion. There are two complementary interpretations of this result. First, input suppliers located abroad may lobby directly over domestic trade policy. For example, this lobbying might occur under the Foreign Agents Registration Act, as described by Gawande, Krishna, and Robbins (2006).[48]

[47]Note also that the coefficicient on the inverse import penetration ratio, proxying for bilateral political economy concerns, is positive in all three specifications, but not statistically significant. This non-result is consistent with the the observation by Maggi and Rodríguez-Clare (2000) that the empirical literature has found mixed results regarding the importance of the import penetration ratio in explaining tariff setting.

[48]Antràs and Padró i Miquel (2011) develop a theory of foreign influence on domestic policy in general, and trade policy in particular. Gawande, Krishna, and Robbins (2006) and Kee, Olarreaga, and Silva (2007) find that foreign lobbies (i.e., producers located abroad) lower US tariffs. While these results demonstrate that foreign interests are represented in policy determination, they are not directly comparable to our results. The reason is that neither paper examines how production chain location influences lobbying incentives. Our result specifically concerns how upstream producers lobby on downstream tariffs, where foreign upstream interests should favor higher downstream final tariffs (simultaneously, they should also favor lower tariffs on the inputs they ship to the U.S.). Both Gawande et al. and Kee et al. examine overall tariffs, mixing final and intermediate tariffs, and so do not speak to our production chain story directly. Gawande, Krishna, and Olarreaga (2012) study how upstream and downstream interests compete in tariff setting, and find empirically that producers in upstream sectors favor higher tariffs in downstream sectors, consistent with the mechanism we emphasize.

Second, domestic firms that use imported inputs may lobby on behalf of upstream suppliers. An important case of this type of lobbying would be lobbying by foreign multinationals that own/operate US production facilities. This lobbying activity is difficult to measure directly, since resident multinationals are not required to register as 'foreign lobbies'. However, it may be quite important, as multinationals are likely to be among the most politically influential firms.

**[To Be Completed: IV and Censoring]**

### 4.2 Temporary Trade Barriers

**[To Be Completed]**

## 5 Conclusion

**[To Be Completed]**

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Table 1: Industry and Country Coverage in the WIOD Database

| Industries | | Countries | |
|---|---|---|---|
| Name | No. | Name | Abbreviation |
| Agriculture, Hunting, Forestry and Fishing | 1 | Australia | AUS |
| Food, Beverages and Tobacco | 3 | Brazil | BRA |
| Textiles and Textile Products | 4 | Canada | CAN |
| Leather and Footwear | 5 | China | CHN |
| Wood and Products of Wood and Cork | 6 | European Union | EUN |
| Pulp, Paper, Paper, Printing and Publishing | 7 | India | IND |
| Coke, Refined Petroleum and Nuclear Fuel | 8 | Indonesia | IDN |
| Chemicals and Chemical Products | 9 | Japan | JPN |
| Rubber and Plastics | 10 | Mexico | MEX |
| Other Non-Metallic Mineral | 11 | Russia | RUS |
| Basic Metals and Fabricated Metal | 12 | South Korea | KOR |
| Machinery, NEC | 13 | Taiwan | TWN |
| Electrical and Optical Equipment | 14 | Turkey | TUR |
| Transport Equipment | 15 | United States | USA |
| Manufacturing, NEC | 16 | | |

Note: Industry numbers denote WIOD industries. We exclude Mining and Quarrying (WIOD industry 2) in all our analysis.

Table 2: Sources and Distribution of Tariff Preferences

| By Preference Program | | | By Direction of Trade | | | |
|---|---|---|---|---|---|---|
| Classification | Count | Percent | Exporter | Importer | Count | Percent |
| Regional Trade Agreement | 631 | 18% | High | High | 518 | 14% |
| Preferential Agreement | 333 | 9% | High | Emerging | 386 | 11% |
| GSP | 1582 | 44% | Emerging | High | 1967 | 55% |
| Other | 1047 | 29% | Emerging | Emerging | 722 | 20% |

Note: Table includes tabulations of observations with non-zero tariff preferences. The first tabulation uses data on bilateral trade agreements and GSP programs recorded by Baier and Bergstrand (2014). The regional trade agreement category includes free trade agreements and customs unions. The preferential trade agreement category includes preferential agreements that do not reach free trade status. The second tabulation records the incidence of tariff preferences by direction of trade between high income versus emerging market economies. High income countries include Australia, Canada, the European Union, South Korea, and the United States.

Table 3: Bilateral Tariffs and Domestic Value Added in Foreign Production

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Log Domestic Value Added: $\ln(DVA^j_{xit})$ | -1.19*** | -0.48*** | -0.87*** | -0.41*** |
| | (0.094) | (0.056) | (0.10) | (0.068) |
| Regional Trade Agreement: $RTA_{ijt}$ | | -5.44*** | | -4.47*** |
| | | (0.32) | | (0.38) |
| Observations | 10,803 | 10,803 | 10,803 | 10,803 |
| R-squared | 0.964 | 0.972 | 0.987 | 0.990 |
| Exporter-Industry-Year | Y | Y | Y | Y |
| Importer-Industry-Year | Y | Y | N | N |
| Importer-Industry-Year-Decile | N | N | Y | Y |

Note: Dependent variable in all columns is the applied bilateral tariff of country $i$ in industry $x$ against exporter $j$ at time $t$: $t^i_{xjt}$. Log Domestic Value Added is domestic value added from the importing country embodied in final production in industry $x$ in the exporting country: $\ln(DVA^j_{ijt})$. Regional Trade Agreement is an indicator that takes the value one is $i$ and $j$ have a regional trade agreement in force at date $t$. Fixed effects are indicated by Y (yes) and N (no) in the table. Standard errors (in parentheses) are clustered by importer-exporter-industry. Significance levels: * $p < .1$ , ** $p < .05$, *** $p < .01$.

Table 4: Bilateral Tariffs and Domestic Value Added in Foreign Production By Sectors and Years

| | | By industry | | |
|---|---|---|---|---|
| | Baseline | Agriculture, Food, etc. | Textiles, Apparel, Footwear | Other Manuf. |
| | (1) | (2) | (3) | (4) |
| Log Domestic Value Added: $\ln(DVA^j_{xit})$ | -0.41*** | -0.43** | -1.42*** | -0.21*** |
| | (0.068) | (0.18) | (0.37) | (0.071) |
| Regional Trade Agreement: $RTA_{ijt}$ | -4.47*** | -4.41*** | | |
| | (0.38) | (0.37) | | |
| Observations | 10,803 | 10,803 | | |
| R-squared | 0.990 | 0.990 | | |

| | By year | | | |
|---|---|---|---|---|
| | 1995 | 2000 | 2005 | 2009 |
| | (5) | (6) | (7) | (8) |
| Log Domestic Value Added: $\ln(DVA^j_{xit})$ | -0.38*** | -0.20** | -0.68*** | -0.44*** |
| | (0.10) | (0.093) | (0.14) | (0.10) |
| Regional Trade Agreement: $RTA_{ijt}$ | -4.45*** | | | |
| | (0.38) | | | |
| Observations | 10,803 | | | |
| R-squared | 0.990 | | | |

Note: Dependent variable in all columns is the applied bilateral tariff of country $i$ in industry $x$ against exporter $j$ at time $t$: $t^i_{xjt}$. Columns (1) is baseline results from prior table. The remaining columns illustrate coefficient heterogeneity across sectors and years, where coefficients are generated by interacting a sector or year indicator with $\ln(DVA^i_{xjt})$. See previous table notes for definitions of $\ln(DVA^j_{xit})$ and $RTA_{ijt}$. All specifications include importer-industry-year-decile and exporter-industry-year fixed effects. Standard errors (in parentheses) are clustered by importer-exporter-industry. Significance levels: * $p < .1$ , ** $p < .05$, *** $p < .01$.

Table 5: Bilateral Tariffs and Domestic Value Added in Foreign Production By Importer Type and Direction of Trade

| | | By importer income group | |
|---|---|---|---|
| | Baseline | High | Emerging |
| | (1) | (2) | (3) |
| Log Domestic Value Added: $\ln(DVA^j_{xit})$ | -0.41*** | -0.17** | -0.54*** |
| | (0.068) | (0.085) | (0.076) |
| Regional Trade Agreement: $RTA_{ijt}$ | -4.47*** | -4.57*** | |
| | (0.38) | (0.38) | |
| Observations | 10,803 | 10,803 | |
| R-squared | 0.990 | 0.990 | |

| | By direction of trade | | | |
|---|---|---|---|---|
| | High to High | High to Emerging | Emerging to High | Emerging to Emerging |
| | (4) | (5) | (6) | (7) |
| Log Domestic Value Added: $\ln(DVA^j_{xit})$ | -0.072 | -0.44*** | -0.30*** | -0.58*** |
| | (0.091) | (0.090) | (0.089) | (0.080) |
| Regional Trade Agreement: $RTA_{ijt}$ | -4.51*** | | | |
| | (0.38) | | | |
| Observations | 10,803 | | | |
| R-squared | 0.990 | | | |

Note: Dependent variable in all columns is the applied bilateral tariff of country $i$ in industry $x$ against exporter $j$ at time $t$: $t^i_{xjt}$. Columns (1) is baseline results from prior table. The remaining columns illustrate coefficient heterogeneity across countries and by directio of trade, where coefficients are generated by interacting an importer or direction of trade flow indicator with $\ln(DVA^i_{xjt})$. See previous table notes for definitions of $\ln(DVA^j_{xit})$ and $RTA_{ijt}$. High income countries include Australia, Canada, the European Union, South Korea, and the United States. All specifications include importer-industry-year-decile and exporter-industry-year fixed effects. Standard errors (in parentheses) are clustered by importer-exporter-industry. Significance levels: * $p < .1$ , ** $p < .05$, *** $p < .01$.

Table 6: Bilateral Tariffs and Domestic Value Added in Foreign Production: IV and Tobit Censored Regressions

| | Linear IV | | Tobit Censored Regression | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Log Domestic Value Added: $\ln(DVA^j_{xit})$ | -0.60*** | -0.48*** | -1.20*** | | -1.28*** | |
| | (0.071) | (0.062) | (0.13) | | (0.14) | |
| Regional Trade Agreement: $RTA_{ijt}$ | -5.27*** | -4.41*** | -8.43*** | -8.37*** | -11.0*** | -10.9*** |
| | (0.28) | (0.24) | (0.45) | (0.46) | (0.61) | (0.60) |
| Agriculture, Food, etc. $\times$ $\ln(DVA^j_{xit})$ | | | | -1.46*** | | -1.15*** |
| | | | | (0.38) | | (0.39) |
| Texiles, Apparel, Footwear $\times$ $\ln(DVA^j_{xit})$ | | | | -2.55*** | | -2.40*** |
| | | | | (0.42) | | (0.44) |
| Other Manufacturing $\times$ $\ln(DVA^j_{xit})$ | | | | -0.83*** | | -1.02*** |
| | | | | (0.14) | | (0.17) |
| Observations | 10,803 | 10,803 | 10,803 | 10,803 | 10,348 | 10,348 |
| Exporter-Industry-Year | Y | Y | Y | Y | Y | Y |
| Importer-Industry-Year | Y | N | Y | Y | Y | Y |
| Importer-Industry-Year-Decile | N | Y | N | N | N | N |

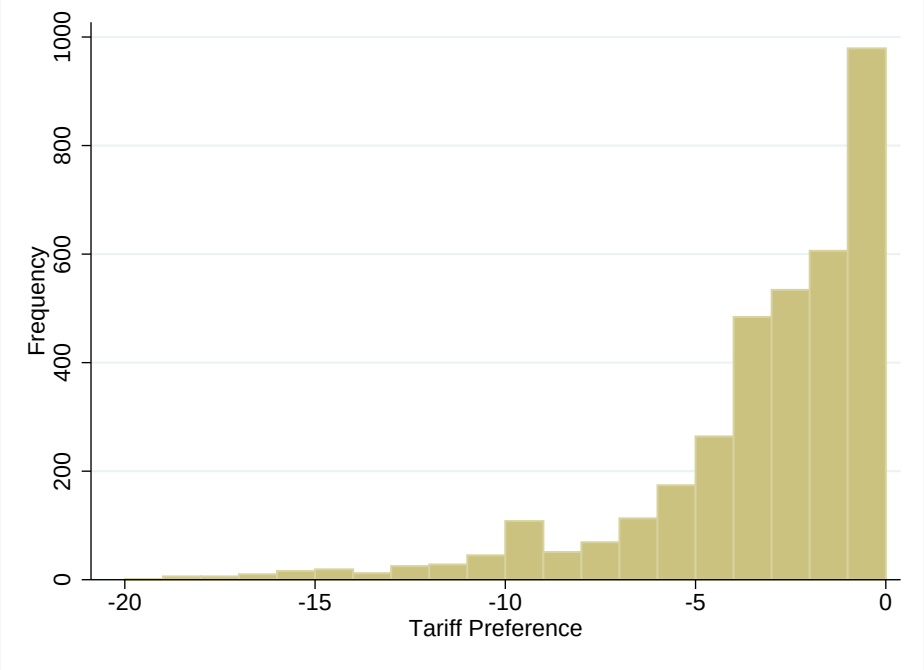
Note: Dependent variable in all columns is the applied bilateral tariff of country $i$ in industry $x$ against exporter $j$ at time $t$: $t^i_{xjt}$. Columns (1) and (2) present linear instrumental variables results, with the instrument for domestic value added described in the text. Columns (3)-(6) present Tobit estimates, correcting for one-sided censoring in columns (3) and (4) and two-sided censoring in columns (5) and (6). Industry name $\times$ $\ln(DVA^j_{xit})$ indicates sector-specific coefficient estimate, estimated by interacting sector indicators with log domestic value added. See previous table notes for definitions of $\ln(DVA^j_{xit})$ and $RTA_{ijt}$. Fixed effects are indicated by Y (yes) and N (no) in the table. Standard errors (in parentheses) are clustered by importer-exporter-industry. Significance levels: * $p < .1$ , ** $p < .05$, *** $p < .01$.

Table 7: Bilateral Tariffs and Foreign Value Added in Domestic Production

| | (1) | (2) | (3) |
|---|---|---|---|
| Inv. Import Penetration Ratio: $p^i_{xt}q^i_{xt}/IM^i_{xjt}$ | 3.0e-06 | | |
| | (2.7e-06) | | |
| DVA Ratio: $DVA^j_{xit}/IM^i_{xjt}$ | -0.0042*** | | |
| | (0.0016) | | |
| FVA Ratio: $FVA^j_{xit}/IM^i_{xjt}$ | 0.000047*** | | |
| | (0.000017) | | |
| Inv. Import Penetration Ratio Quantiles | | 0.0079 | |
| | | (0.024) | |
| DVA Ratio Quantiles | | -0.031*** | |
| | | (0.0057) | |
| FVA Ratio Quantiles | | 0.058** | |
| | | (0.024) | |
| Log Inv. Import Penetration Ratio | | | 0.50*** |
| | | | (0.058) |
| Log DVA Ratio | | | -0.41*** |
| | | | (0.057) |
| Regional Trade Agreement: $RTA_{ijt}$ | -6.01*** | -5.54*** | -5.36*** |
| | (0.35) | (0.33) | (0.32) |
| Observations | 10,617 | 10,617 | 10,617 |
| R-squared | 0.971 | 0.972 | 0.972 |

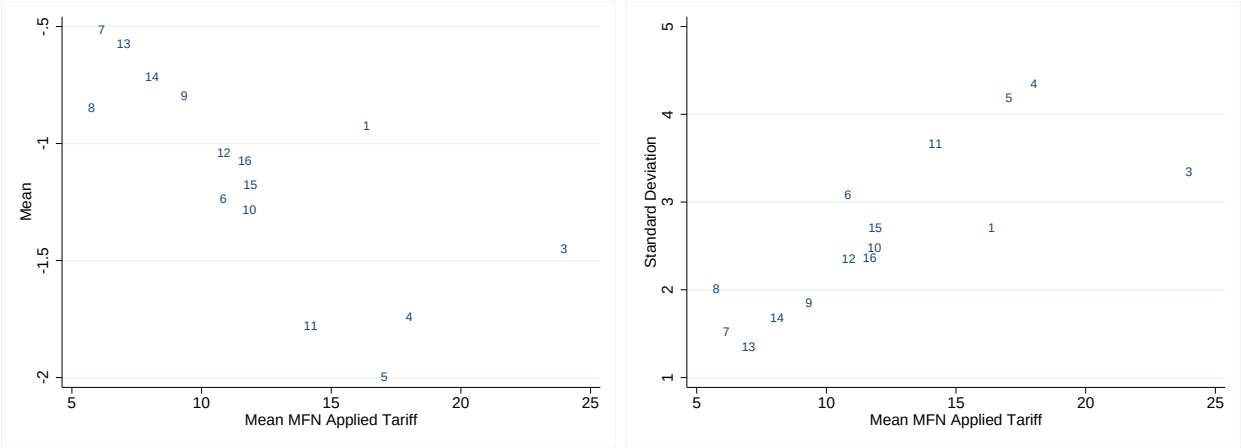
Note: Dependent variable in all columns is the applied bilateral tariff of country $i$ in industry $x$ against exporter $j$ at time $t$: $t^i_{xjt}$. The inverse import penetration ratio is final goods production in country $i$ and industry $x$ at time $t$ ($p^i_{xt}q^i_{xt}$) divided by imports by country $i$ in industry $x$ at time $t$ ($IM^i_{xjt}$). FVA Ratio is foreign value added in country $i$'s final goods production in industry $x$ at time $t$ ($FVA^i_{xt}$) divided by $IM^i_{xjt}$. The DVA Ratio is defined similarly. See previous table notes for definitions of $DVA^j_{ijt}$ and $RTA_{ijt}$. The ratio quantiles are formed by binning the data by quantiles of the ratio indicated, and assigning the bin number to the corresponding observations. Log Inv. Import Penetration Ratio and Log DVA Ratio are natural logs of the ratios. In column (3), the log of the FVA Ratio is omitted because it is collinear with the log of the Inv. Import Penetration Ratio, given the importer-industry-year fixed effect in the regression. All columns include importer-industry-year and exporter-industry-year fixed effects. Standard errors (in parentheses) are clustered by importer-exporter-industry. Significance levels: * $p < .1$ , ** $p < .05$, *** $p < .01$.

Figure 1: The Distribution of Tariff Preferences




Note: Tariff preference equals the applied bilateral tariff for importer $i$ against exporter $j$ in industry $s$ minus the MFN applied tariff for importer $i$ in industry $s$. The histogram includes only observations for which applied bilateral tariffs are lower than MFN (i.e., non-zero preferences), and excludes 30 observations with preferences $< -20$ for legibility. The bin width is set to 1 percentage point.

Figure 2: Mean and Standard Deviation of Tariff Preferences versus MFN Tariffs, by Sector

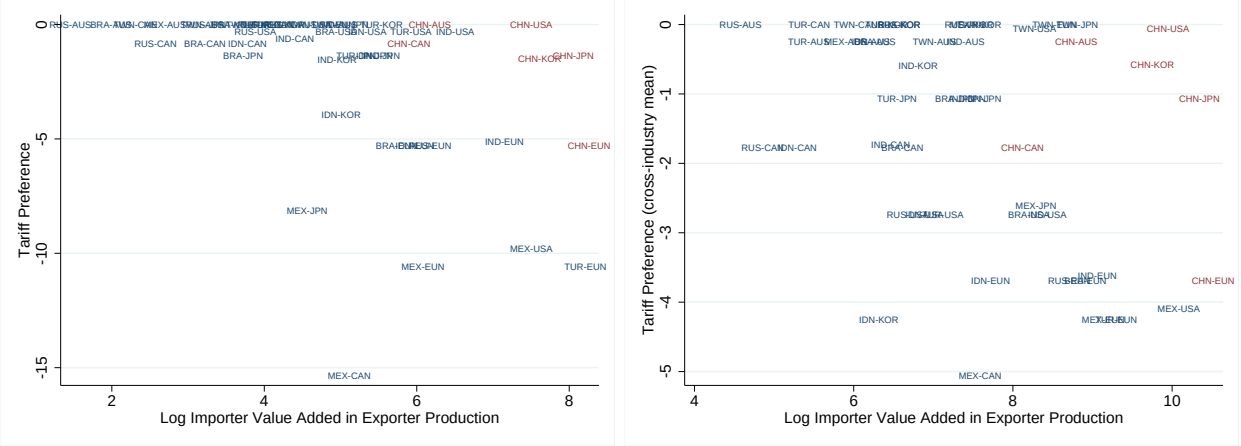



(a) Mean of Tariff Preferences

(b) Standard Deviation of Tariff Preferences

Note: Tariff preference equals the applied bilateral tariff for importer $i$ against exporter $j$ in industry $s$ minus the MFN applied tariff for importer $i$ in industry $s$. Both means and standard deviations are computed by sector, pooling all importer-exporter-year observations within sector, including those with zero preferences. The markers denote WIOD sector numbers, included in Table 1.

Figure 3: Tariff Preferences and Domestic Value Added in Foreign Final Goods




(a) Textiles and Apparel

(b) All Manufacturing Industries

Note: Figure includes high income importers and emerging economies exports in 2005. High income countries include Australia, Canada, the European Union, South Korea, and the United States. Emerging economies include 9 countries in our sample. Textiles and Apparel is WIOD sector 4, and All Manufacturing is WIOD sectors 4-16. Labels indicate exporter-importer pair.

# A The Optimal Bilateral Tariff in General Equilibrium

This appendix derives the optimal bilateral tariff under general equilibrium, but political economy and holding $\vec{\nu}$ fixed. (Endogenizing $\vec{\nu}$ TBD in the next draft.) Country $i$'s optimal tariff on final good $s \in \mathcal{S}$ imposed against country $j \in \mathcal{C}$ maximizes the indirect utility of the representative consumer according to:

$$\tau_{sj}^{i} = \arg\max_{\tau_{sj}} \quad V\big(\vec{p^{i}}(\vec{\tau}), I(\vec{p}(\vec{\tau}))\big), \tag{26}$$

where $\vec{p}$ represents the $(1 \times SC)$ vector of final goods prices across countries and sectors and $\vec{\tau}$ describes the vector of tariffs worldwide (where we follow custom defining $\tau$ as one plus the ad valorem tariff throughout). Here and later, we partition the world price vector into the 'domestic' (country $i$) $(1 \times S)$ price vector $\vec{p^{i}}$ and the $(1 \times S(C-1))$ vector of final goods prices in every other country, $\vec{p^{*}}$. National income is given by:[49]

$$\begin{aligned} I &= \sum_{s\in\mathcal{S}} r_{si}^{i}\nu_{si}^{i} + \sum_{s\in\mathcal{S}}\sum_{c\neq i\in\mathcal{C}} r_{si}^{c}\nu_{si}^{c} + \sum_{s\in\mathcal{S}}\sum_{c\neq i\in\mathcal{C}} \underbrace{(p_{s}^{i} - p_{s}^{c})M_{sj}^{i}(\vec{p}, I; \vec{\nu})}_{\equiv R(\vec{p},I;\vec{\nu})}, \\ &= \vec{p^{i}}\cdot\vec{q^{i}}(\vec{\nu}) + R(\vec{p}, I; \vec{\nu}) - \underbrace{\vec{r_{*}^{i}}\cdot\vec{\nu_{*}^{i}}}_{\equiv\psi_{*}^{i}(\vec{p^{i}});\vec{\nu})} + \underbrace{\vec{r_{i}^{*}}\cdot\vec{\nu_{i}^{*}}}_{\equiv\psi_{i}^{*}((\vec{p^{*}});\vec{\nu})}. \end{aligned} \tag{27}$$

where $\vec{q^{i}}(\vec{\nu})$ is the $(1 \times S)$ vector of country $i$'s domestic production of each good, $R(\vec{p}, I; \vec{\nu})$ is total tariff revenue, and $\psi_{*}^{i}(\vec{p^{i}}); \vec{\nu})$ and $\psi_{i}^{*}((\vec{p^{*}}); \vec{\nu})$ are the total returns paid to foreign value added used in country $i$'s domestic production, and the total returns paid to country $i$'s value added embodied in all foreign production, as defined in the main text.

The first order condition of country $i's$ maximization problem is:

$$V_{\tau_{sj}} = \nabla V_{\vec{p^{i}}}\cdot D\vec{p^{i}}_{\tau_{sj}^{i}} + V_{I}\nabla I_{\vec{p}}\cdot D\vec{p}_{\tau_{sj}^{i}} = 0$$

Using Roy's identity and substituting in the derivative of (27) with respect to the bilateral tariff yields:

$$V_{\tau_{sj}} = V_{I}\left\{-\vec{E_{*}^{i}}\cdot D\vec{p^{*}}_{\tau_{sj}^{i}} + \vec{t^{i}}\vec{p^{*}}D\vec{E_{*}^{i}}\cdot D\vec{p^{*}}_{\tau_{sj}^{i}} + \nabla\psi_{h}^{*}\cdot D\vec{p^{*}}_{\tau_{sj}^{i}} - \nabla\psi_{*}^{i}\cdot D\vec{p^{i}}_{\tau_{sj}^{i}}\right\} = 0, \tag{28}$$

where $\vec{E_{*}^{i}}$ represents the $(1 \times S(C-1))$ vector of every country's exports of each good to country $i$, $\nabla\psi_{h}^{*}$ is the $(1 \times S(C-1))$ gradient of the change in home value added returns used in foreign production with respect to the foreign price vector, $\vec{p^{*}}$, and $\nabla\psi_{*}^{i}$ is the $(1 \times S)$ gradient of the change in foreign value added returns used in home production with respect to the home price vector, $\vec{p^{i}}$.

After some algebra, and using $\mathbf{\Lambda^{i}}$ to represent a $(S \times S(C-1))$ matrix describing the

[49] $\vec{r_{*}^{i}}$ ($\vec{\nu_{*}^{i}}$) are the $(1 \times S(C-1))$ vectors of value added prices (quantities) embodied in country $i$'s domestic production in every sector $S$ from each of $i$'s $C-1$ trading partners; $\vec{r_{i}^{*}}$ ($\vec{\nu_{i}^{*}}$) are the $(1 \times S(C-1))$ vectors of value added prices (quantities) of country $i$'s value added embodied in every sector $S$ of each of its $C-1$ trading partners' production.

relative price responses to a change in the bilateral tariff,[50] we have:

$$\left(-\vec{E}^i_* + \vec{t^i}\vec{p^*}D\vec{E}^i_* + \nabla\psi^*_i - \nabla\psi^i_*\mathbf{\Lambda^i}\right)\cdot\vec{1} = 0. \tag{29}$$

Calculating the inner product and collecting terms yields:

$$t^i_{xj}p^j_x E^i_{xj} = \frac{dE^j_{xj}}{dp^j_x} - \Delta\psi^*_i - \Delta\psi^i_* - \Omega^R_{xj}E^i_{xj}, \tag{30}$$

where $\Omega^R_{xj} \equiv \frac{1}{E^i_{xj}}\left[\sum_{c\neq j}(E^i_{xc} - t^i_{xc}p^c_x E^i_{xc}) + \sum_{c\in C}\sum_{s\neq x}(E^i_{sc} - t^i_{sc}p^c_s E^i_{sc})\right]$ captures the effect of indirect price changes on tariff revenue via trade volumes from trading partners other than country $j$ and sectors other than $x$. The total change in the returns to value added from the tariff change are given by:

$$\begin{aligned}
\Delta\psi^*_i &\equiv \nabla\psi^*_i\cdot\vec{1} = \sum_s\sum_{c\neq i}\left(\frac{dr^c_{si}}{dp^c_s}\nu^c_{si}\right),\\
\Delta\psi^i_* &\equiv \nabla\psi^i_*\mathbf{\Lambda^i}\cdot\vec{1} = \sum_s\sum_{c\neq i}\frac{dr^i_{sc}}{dp^i_s}\frac{\nu^i_{sc}}{|\lambda^i_s|},
\end{aligned}$$

Note that we have rewritten $\Delta\psi^i_*$ to absorb the $\lambda$ terms, where $\lambda^i_s \equiv \frac{1}{\Lambda^i_s}$ s.t. $\Lambda^i_s = \sum_{c\neq i}\frac{\Lambda^i_{sc}}{S(C-1)}$ captures the cross-country average ratio of foreign to home price responses to the tariff. Isolating $t^i_{xj}$ in Equation (30) yields the bilateral optimal tariff expression:

$$t^i_{xj} = \frac{1}{\hat{\epsilon}^{ji}_x}\left[1 - \frac{r^j_{xi}\nu^j_{xi}}{p^j_x M^i_{xj}}\varepsilon^{rj}_{xi} - \frac{r^i_{x*}\nu^i_{x*}}{p^i_x M^i_{xj}}\frac{\varepsilon^{ri}_{x*}}{|\lambda^i_x|} - \Omega^i_* - \Omega^*_i - \Omega^R_{xj}\right], \tag{31}$$

where $\Omega^i_*$, $\Omega^*_i$, and $\Omega^R_{xj}$ capture any potential general equilibrium spillovers via price changes

[50] $\mathbf{\Lambda^i} \equiv \frac{1}{S(C-1)}D\vec{p^i}_{\tau^i_{xj}}\cdot D\vec{p^{*-1}}_{\tau^i_{xj}}$ where $\vec{Dp^i}$ is the $(S\times 1)$ derivative of the local price vector with respect to $\tau^i_{xj}$ and (taking some license with notation) $D\vec{p^{*-1}}_{\tau^i_{xj}}$ to represent the $(1\times S(C-1))$ vector of the (element by element) inverse of the foreign price vector; thus, each element $\Lambda^i_{sc} \equiv \frac{dp^i_s}{d\tau^i_{xj}}/\frac{dp^c_s}{d\tau^i_{xj}}$.

in other sectors or other countries as defined in the decompositions below.

$$\begin{aligned}
\frac{\Delta\psi_i^*}{M_{xj}^i} &= \frac{1}{M_{xj}^i}\sum_s\sum_{c\neq i}\left(\frac{dr_{si}^c}{dp_s^c}\nu_{si}^c\right) \\
&= \sum_s\sum_{c\neq i}\left(\frac{r_{si}^c\nu_{si}^c}{p_s^c M_{xj}^i}\right)\underbrace{\left(\frac{dr_{si}^c}{dp_s^c}\frac{p_s^c}{r_{si}^c}\right)}_{\equiv\varepsilon_{si}^{rc}} \\
&= \underbrace{\frac{r_{xi}^j\nu_{xi}^j}{p_x^j M_{xj}^i}\varepsilon_{xi}^{rj}}_{\text{direct effect}} + \underbrace{\sum_{c\neq i}\sum_{s\neq x}\frac{r_{si}^c\nu_{si}^c}{p_s^c M_{xj}^i}\varepsilon_{si}^{rc} + \sum_{c\neq i,j}\frac{r_{xi}^c\nu_{xi}^c}{p_x^c M_{xj}^i}\varepsilon_{si}^{rc}}_{\text{indirect (GE) effects } \equiv\Omega_i^*},
\end{aligned}$$

and,

$$\begin{aligned}
\frac{\Delta\psi_*^i}{M_{xj}^i} &= \sum_s\sum_{c\neq i}\left(\frac{r_{sc}^i\nu_{sc}^i}{p_s^i M_{xj}^i}\right)\underbrace{\left(\frac{dr_{sc}^i}{dp_s^i}\frac{p_s^i}{r_{sc}^i}\right)}_{\equiv\varepsilon_{sc}^{ri}}\frac{1}{|\lambda_s^i|} \\
&= \underbrace{\sum_{c\neq i}\frac{r_{xc}^i\nu_{xc}^i}{|\lambda_x^i|p_x^i M_{xj}^i}\varepsilon_{xc}^{ri}}_{\text{direct effect}} + \underbrace{\sum_{s\neq x}\sum_{c\neq i}\frac{r_{sc}^i\nu_{sc}^i}{|\lambda_s^i|p_s^i M_{xj}^i}\varepsilon_{sc}^{ri}}_{\text{indirect (GE) effects } \equiv\Omega_*^i} \\
&\cong \frac{r_{x*}^i\nu_{x*}^i}{|\lambda_x^i|p_x^i M_{xj}^i}\varepsilon_{x*}^{ri} + \sum_{s\neq x}\frac{r_{s*}^i\nu_{s*}^i}{|\lambda_s^i|p_s^i M_{xj}^i}\varepsilon_{s*}^{ri}. \qquad \diamond
\end{aligned}$$