Global Value Chains and Trade Policy*

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Abstract

How do global value chain (GVC) linkages modify countries' incentives to impose import protection? Are these linkages important determinants of trade policy in practice? We develop a new approach to modeling tariff setting with GVCs, in which optimal policy depends on the nationality of value-added content embedded in home and foreign final goods. Theory predicts that discretionary tariffs will be decreasing in the domestic content of foreign-produced final goods and the foreign content of domestically-produced final goods. Using data for 14 countries between 1995 and 2015, we show that governments set lower tariffs and curb their use of temporary trade barriers where GVC linkages are strongest, consistent with theory. Turning to quantitative model counterfactuals, we find that severing GVC linkages would lead to the disappearance of tariff preferences. Further, targeted policies to decouple China from GVCs would increase the optimal tariff set by G7 countries on Chinese exports.

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In the modern global economy, most final goods are "made in the world" by combining inputs from many countries via global value chains (GVCs). The rising importance of GVCs has attracted widespread interest among business leaders and policy makers. For example, the World Trade Organization is exploring how trade policy institutions can be modernized to suit this new reality.[1] Value chain concerns were also prominent in debates about the United Kingdom's exit from the European Union and the recent re-design of the North American Free Trade Agreement. This policy emphasis derives from a tacit expectation that GVC linkages alter the conventional calculus of trade protection; that by knitting together the interests of firms and workers across national boundaries, GVCs are reshaping the consequences of tariffs and other border barriers, and hence the objectives of government policy.

Despite the attention afforded to GVCs by practitioners, theoretical and empirical analyses of the role of GVCs in shaping trade policy are scarce. One reason is that data sources and methods to measure GVC linkages have only been developed over the past decade. A second reason is that GVCs take many forms: some are sequential in nature, others are are not; some are organized within firms, others at arms length; some feature bilateral bargaining over prices, others allow for market-determined prices; some are bilateral, others involve many countries; and so on. This variety in the structure of GVCs frustrates policy analysis, by making it difficult to obtain general lessons or predictions for policy.

In this paper, we leverage a value-added view of the production process to advance both the theory and empirics of trade policy with GVCs. We build on the idea that GVCs are ultimately vehicles for trade in factor services.[2] This factor trade severs the link between the location where goods are produced and the nationality of who earns the income generated from that production. Developing this insight, we show that government objectives over final goods tariffs can be characterized in terms of two basic GVC features: the pattern of trade in factor services, which defines how income generated by final goods production is apportioned across countries, and the system of pass-through elasticities that govern how income paid to agents engaged in the GVC depends on final goods prices. This approach reduces a complex trade policy problem to a tractable, intuitive one. Further, because GVC income is tied to the value-added content of final goods, we are able to capitalize on advances in measuring trade in value added to connect theory with trade policy empirics.

Embedding this production structure into workhorse models of trade policy, we show that final goods tariffs will be decreasing in both the amount of domestic GVC income generated

[1] See the WTO's Made in the World Initiative and the 2014 World Trade Report [WTO (2014)]. See also Baldwin (2012) and Hoekman (2014).

[2] As in models of task trade [Grossman and Rossi-Hansberg (2008)] and factor exchange [Adão, Costinot and Donaldson (2017)], we abstract from trade at intermediate stages of processing.

by production of foreign final goods and the amount of foreign GVC income generated by production of domestic final goods. We assemble rich data on bilateral applied tariffs, temporary trade barriers (TTBs), and value-added contents to document that observed trade policies are correlated with GVC linkages, consistent with this theory. We then evaluate the impact of GVC linkages on policy via counterfactuals in a quantitative version of the model.

We develop the theory in several steps. In Section 1, we first characterize the relationship between GVC linkages and unilaterally-optimal tariffs on final goods in a benchmark two-good, two-country model with specific factors, wherein GVC linkages are exogenous. We then demonstrate that the key insights are robust to allowing for endogenous reorganization of GVCs in response to tariffs, and we assess the mechanics of input tariffs in the model. Preparing to engage data in Section 2, we extend the model to include many countries and goods, as well as political economy motives for policy, to analyze optimal *bilateral* tariffs. Finally, in Section 3, we provide a version of this many country model that is suitable for quantitative analysis.

In these all these settings, final goods tariffs deviate from the standard "inverse export supply elasticity rule" for two key reasons. First, when foreign producers use inputs from the home country in production, the home (importing) country's incentive to manipulate the terms of trade is diminished. Put simply, an importer's tariff pushes down the price that foreign producers receive for their output, which hurts upstream domestic input suppliers to that foreign industry. Thus, the home government optimally sets a lower tariff on imports that contain more home-country content. Second, when home producers use foreign inputs in production, foreigners capture some of the protectionist rents from higher home tariffs. So, the home government's desire to apply import protection is again diminished.[3] In addition to these two basic forces, political economy concerns interact with GVC linkages in extended versions of the model.[4] If the government affords additional political weight to domestic suppliers of inputs used in foreign production, then the tariff liberalizing effect via the first channel will be stronger. Conversely, if the government affords political weight to foreign suppliers of inputs to domestic producers, then these political concerns may weaken (or even overturn) the second channel.

Building on this foundation, we estimate the influence of GVC linkages on bilateral trade policies, where governments have scope to implement discretionary protection.[5] We first

[3]Note that this second effect arises even if the government has no ability (or motive) to manipulate its terms of trade; this constitutes a distinct international externality that travels through domestic prices.

[4]The model also delivers the standard result that politically-optimal tariffs rise if the government favors domestic producers of final goods, which is an important empirical consideration [Goldberg and Maggi (1999); Gawande and Bandyopadhyay (2000)].

[5]We measure GVC linkages by computing the value-added content of final goods, based on input-output methods and data from the World Input-Output Database.

examine bilateral tariff preferences – downward deviations in applied bilateral tariffs from multilateral MFN levels. We then study the use of temporary trade barriers (antidumping, safeguard, and countervailing duties). Theory motivates the empirical specifications we adopt, and we control for confounding factors via observable proxies and fixed effects. Further, we attend to the institutional environment in which policy is set by accounting for censoring of applied bilateral tariffs due to the MFN rule.[6] We also explore how economic forces shape coefficient heterogeneity, showing that upstream and downstream product differentiation mediate the relationship between GVC linkages and observed tariffs.

We find results that are consistent with theoretical predictions: higher domestic content in foreign final goods, and higher foreign content in domestic goods, are associated with systematically larger tariff preferences. Further, the estimated influence of GVC linkages on tariffs is stronger when we correct for censoring induced by the MFN rule. Moreover, domestic content is more strongly correlated with tariffs when it originates in highly-differentiated upstream sectors, indicative of a strong pass-through from final goods prices to returns to upstream factors.[7] Finally, we show that the use of temporary trade barriers (TTBs) is systematically related to GVC linkages. Honing in on an important segment of this data, we find that domestic content in Chinese goods appears to deter countries from imposing TTBs on China.

In Section 3, we turn to a quantitative version of the model to shed further light on model mechanics and evaluate the impact of GVC linkages on optimal tariffs. In this, we add additional supply-side assumptions to the model of bilateral tariffs with political economy, which yields a gravity-type structure for trade in final goods and GVC inputs. Further, we develop a novel Roy-Frèchet mechanism to describe how GVC input suppliers sort into global value chains.

Calibrating the model to match an initial observed trade equilibrium, we then examine how optimal tariffs change when GVC linkages are exogenously severed, whether globally or at the bilateral level. We find that eliminating GVCs nearly stamps out preferential tariffs in the model. Moreover, targeted policies imposed by the G7 to restrict the supply of GVC inputs to China would lead G7 countries to optimally impose higher tariffs on Chinese exports. Lastly, reductions in exogenous (iceberg) GVC frictions between 1995 and 2015 imply a reduction in global mean tariffs of about 2 percentage points, which is sizable relative to the 4.5 percentage point decline in mean observed tariffs over this period.

Our study is related to several branches of the trade policy literature. Our framework

[6] In supplemental results, we explore how the results differ across trade policy regimes, whether tariffs are set via regional trade agreements or other policy regimes (e.g., the Generalized System of Preferences).

[7] Domestic content also is also more strongly negatively correlated with tariffs in final goods sectors that are differentiated, which likely feature lower export supply elasticities.

complements work by Ornelas and Turner (2008, 2012) and Antràs and Staiger (2012), who analyze how bilateral bargaining under incomplete contracts among value chain partners alters the mapping from tariffs to prices, and therefore optimal trade policy for both final goods and inputs. Caliendo et al. (2023) and Antràs et al. (forthcoming) study optimal tariffs in quantitative models with roundabout production and imperfect competition, while Beshkar and Lashkaripour (2020) conduct related analysis of optimal policy in a quantitative Ricardian framework with perfect competition. One takeaway from these contributions is that optimal input tariffs depend critically on the precise modelling assumptions one adopts, as recognized by Antràs and Chor (2022). In contrast, the core theoretical findings for final goods tariffs that we emphasize hold in various contexts, as we discuss below.

Our theory is also related to Blanchard (2007, 2010), which show that foreign direct investment and international ownership alter the mapping from prices to income, and thus optimal tariffs.[8] In contrast to this work on ownership, our theory links observable input trade patterns to bilateral tariffs. In this way, it directs attention to the most important dimension of GVC activity: the input linkages that accompany GVCs. Because these input linkages are both pervasive and large quantitatively – foreign value added accounts for 20 percent of the value of final manufacturing output in many countries, and more than 50 percent in some countries and sectors – the role of input linkages is fruitful, yet previously unexplored, territory for both theoretical and empirical analysis.

Our results also contribute to a prominent literature studying terms-of-trade motives for protection [Broda, Limão and Weinstein (2008); Bagwell and Staiger (2011); Ludema and Mayda (2013); Bown and Crowley (2013); Soderbery (2018); Nicita, Olarreaga and Silva (2018)]. Drawing on this work, we examine how trade in value-added content modifies policy setting, and we are the first (to our knowledge) to demonstrate the relevance of terms-of-trade concerns for *bilateral* tariff policy. Relatedly, two recent papers leverage the value-added approach we develop in this paper in different contexts. Using data on Chinese processing trade with Asian partners, Ludema et al. (2021) find that input customization and political economy forces play an important role in shaping the relationship between GVCs and trade protection. Focusing instead on the discretionary removal of trade protection after the creation of the WTO, Bown, Erbahar and Zanardi (2021) find that bilateral DVA linkages predict the probability that duties will be removed, consistent with our findings.

[8] Our paper speaks to related empirical work on the influence of multinational firms on trade policy. Blanchard and Matschke (2015) show that the United States offers preferential market access to destinations that host affiliates of US multinationals, and Jensen, Quinn and Weymouth (2015) find that US multinationals refrain from filing antidumping disputes against countries with which they conduct intrafirm trade.

1 Theory

In this section, we describe how global value chain linkages influence tariff setting in a two-country, two-good (2x2) environment, in the tradition of Johnson (1953-1954). To maintain focus, we restrict attention to a single trade policy instrument: an ad-valorem tariff applied to imports of a final good that is produced via a global value chain.

We lay out the baseline model in Section 1.1, in which we assume that the final good is produced by combining domestic and foreign specific factors. In Section 1.2, we characterize the implicit function that links final goods tariffs to the (potentially observable) domestic value-added content of foreign goods and the foreign value-added content of domestic goods. We also provide a comparative statics proposition that traces exogenous changes in the endowments of the specific factors through to optimal tariffs in Section 1.3. We then discuss two extensions of the baseline model. First, in Section 1.4, we relax the specific factors assumptions to allow for endogenous changes in GVC input use in response to tariffs. Second, we describe how input tariffs can be incorporated into the theory in Section 1.5.

1.1 The 2x2 Benchmark Model

We start by describing the economic environment, and then we characterize the economic equilibrium as a function of the tariff.

1.1.1 Economic Environment

Two countries, indexed by $c \in \{h, f\}$ and referred to as Home and Foreign, are populated with a continuum of identical agents who produce, trade, and consume two goods, indexed by $s \in \{x, y\}$. Let good y serve as the freely-traded numéraire, and let p^c denote the local price of good x measured in units of good y in country c. Together, the residents of each country hold claims on all of the country's endowments.

Preferences Let preferences in each country be represented by the aggregate utility function: $U(d_x^c, d_y^c)$, where d_s^c denotes total consumption of good s in country c.

Factor Endowments There are two types of factors. The first is a homogeneous factor (e.g., undifferentiated labor), which is perfectly mobile across sectors, but immobile across countries. The second is a set of specific factors, which we refer to as "GVC inputs." For now, assume that these GVC inputs are specific to the destination country and sector in which they are used to produce final goods. Let ν_h^c (ν_f^c) denote the quantity of the Home (Foreign) GVC input used in production of final good x in country c, and let $\vec{\nu}^c \equiv (\nu_h^c, \nu_f^c)$. Regarding notation, superscripts will denote country location of final production, and subscripts identify the origin country of the GVC input.

Technology Goods are produced under constant returns by atomistic firms in perfectly competitive markets. The numéraire good y is produced using homogeneous labor, while good x is produced by combining labor with GVC inputs. Production technologies are summarized by the following production functions:

$$q_x^c = f_x^c(l_x^c, \nu_h^c, \nu_f^c), \qquad \text{and} \qquad q_y^c = l_y^c, \tag{1.1}$$

where q_s^c is output of good s in country c, and l_s^c is the quantity of homogeneous labor used in production of good s.

This stylized depiction of the production process captures two essential features of global value chains. First, both domestic and foreign factors of production are used to produce output in a GVC. Second, GVCs often feature a high degree of input specificity and lock-in between buyers and suppliers, as emphasized by Antràs and Staiger (2012). In our model, this lock-in is manifest as factor specificity. We discuss how payments to these specific factors are determined via cooperative bargaining below.

Tariffs and Timing We assume that x is Home's natural import good and allow the Home government to impose an ad-valorem tariff on imports, applied to the Foreign selling price.[9] The government chooses its tariff to maximize aggregate indirect utility of Home residents, subject to balanced budget constraints and global market clearing conditions. Taking the tariff as given, firms maximize profits and consumers maximize welfare. The government has perfect foresight and there is no uncertainty in the model.

Both countries are assumed to be "large," in that government tariff choices may affect market-clearing prices. Following common practice [e.g. Bagwell and Staiger (1999)], we rule out the Metzler and Lerner paradoxes to ensure that an increase in the home country's tariff causes the price of the imported good to rise at Home and fall abroad. That is, using τ to represent one plus the tariff rate and $\tilde{p}^c$ to represent the equilibrium price of good x in country c, we assume $\frac{d\tilde{p}^f}{d\tau} \leq 0 \leq \frac{d\tilde{p}^h}{d\tau}$.

[9] Export taxes are ruled out, since they are seldom used in practice, and even unconstitutional in the United States. Beshkar and Lashkaripour (2020) offer an elegant theoretical characterization of optimal trade taxes, which allows for both import and export taxes.

1.1.2 Model Solution

Production By choice of units, the technology for the numéraire good y normalizes the equilibrium wage to one in both countries. Profit maximization by atomistic firms and the local labor market clearing condition then determine the allocation of labor across sectors according to:

$$l_x^c(p^c;\vec{\nu}^c) = \arg\max_{l_x^c} \; p^c f_x^c(l_x^c, \nu_h^c, \nu_f^c) - l_x^c, \tag{1.2}$$

$$l_y^c(p^c;\vec{\nu}^c) = L^c - l_x^c(p^c;\vec{\nu}^c), \tag{1.3}$$

where L^c is the total local labor endowment in country c and $l_x^c + l_y^c \leq L^c$. Substituting these labor allocation functions into the production functions yields the supply function for each good:

$$q_x^c(p^c;\vec{\nu}^c) = f_x^c(l_x^c(p^c;\vec{\nu}^c);\vec{\nu}^c) \tag{1.4}$$

$$q_y^c(p^c;\vec{\nu}^c) = l_y^c(p^c;\vec{\nu}^c). \tag{1.5}$$

Consistent with perfect competition, GVC inputs capture all residual profit (quasi-rent) from local final good production. For producers in c, residual profit is defined as $\pi_x^c(p^c;\vec{\nu}^c) \equiv p^c q_x^c(p^c;\vec{\nu}^c) - l_x^c(p^c;\vec{\nu}^c)$, with $\frac{\partial \pi_x^c(p^c;\vec{\nu}^c)}{\partial p^c} > 0$ as long $q_x^c(p^c;\vec{\nu}^c) > 0$, by Hotelling's lemma.

We assume these profits are split among owners of the specific factors via a cooperative game according to a weighted Nash bargaining solution. We briefly describe the solution here, drawing on Appendix A.1. Let payments by the downstream producer to GVC input suppliers from d be π_{xd}^c, where these payments exhaust total profits: $\pi_x^c(p^c;\vec{\nu}^c) = \sum_d \pi_{xd}^c$. If the constant Nash bargaining weights are denoted $\alpha_d^c > 0$, then payments are given by: $\pi_{xd}^c \equiv \pi_{xd}^c(p^c;\vec{\nu}^c) = \alpha_d^c \pi_x^c(p^c;\vec{\nu}^c)$. The return per unit of factor supplied is then $r_d^c(p^c;\vec{\nu}^c) \equiv \frac{\pi_{xd}^c(p^c;\vec{\nu}^c)}{\nu_d^c}$. Further, it is straightforward to see that $\frac{\partial r_d^c(p^c;\vec{\nu}^c)}{\partial p^c} > 0$, so payments to GVC input suppliers are increasing in the price of downstream output.[10]

[10] While we have adopted a Nash bargaining approach to splitting the surplus for concreteness here, any micro-foundation in which payments to GVC input suppliers are increasing in price of downstream output would suffice.

Consumption Given preferences, aggregate demand and indirect utility depend only on local prices and aggregate national income according to:

$$d_x^c(p^c, I^c) = \arg\max_{d_x^c} \quad U(d_x^c, d_y^c) \quad s.t. \quad d_y^c + p^c d_x^c \leq I^c, \tag{1.6}$$

$$d_y^c(p^c, I^c) = I^c - p^c d_x^c(p^c, I^c), \tag{1.7}$$

$$V(p^c, I^c) = U(d_x^c(p^c, I^c), d_y^c(p^c, I^c)), \tag{1.8}$$

where $V(\cdot)$ is indirect utility and I^c is national income.

National Income National income is the sum of factor payments plus tariff revenue (R^c):

$$I^c = L^c + r_c^h(p^h; \vec{\nu}^h)\nu_c^h + r_c^f(p^f; \vec{\nu}^f)\nu_c^f + R^c. \tag{1.9}$$

Home tariff revenue is $R^h = (p^h - p^f)M_x(\vec{p}, I^h; \vec{\nu}^h)$, where $M_x(\cdot) \equiv d_x^h(p^h, I^h) - q_x^h(p^h; \vec{\nu}^h)$ is Home's imports of good x and $\vec{p} \equiv (p^h, p^f)$.[11] Because income depends on tariff revenue, and tariff revenue depends on income, Equation (1.9) implicitly defines income as a function of prices and GVC input use: $I^c \equiv I^c(\vec{p}; \vec{\nu})$.

Equivalently, national income can be written (implicitly) as the sum of the value of domestic final good production at local prices and tariff revenue, less payments to foreign GVC inputs used in domestic production (FVA), plus income earned by domestic GVC inputs used in foreign production (DVA):

$$I^c = p^c q_x^c(p^c; \vec{\nu}^c) + q_y^c(p^c; \vec{\nu}^c) + R^c - FVA^c + DVA_c, \tag{1.10}$$

$$\text{where } FVA^c \equiv r_j^c(p^c; \vec{\nu}^c)\nu_j^c \text{ and } DVA_c \equiv r_c^j(p^j; \vec{\nu}^j)\nu_c^j. \tag{1.11}$$

where $j \neq c$. The first three components of this expression mirror standard models. The last two components reflect GVC linkages. Foreshadowing results to come, note that FVA^c and DVA_c depend on final goods prices via the endogenous return to GVC inputs. Because tariffs influence final goods prices, trade policy affects income in a non-standard way in the presence of GVCs.

Market Clearing and Equilibrium Prices The relative price of x in Home is determined by its tariff and the foreign equilibrium price according to the no-arbitrage condition:

$$p^h(\tau, p^f) = \tau p^f. \tag{1.12}$$

[11] Since Foreign practices free trade, $R^f = 0$.

The equilibrium Foreign price ($\tilde{p}^f$) is then determined by market clearing:

$$d^h_x(p^h(\tau,\tilde{p}^f),\tilde{p}^f;\vec{\nu}) + d^f_x(p^h(\tau,\tilde{p}^f),\tilde{p}^f;\vec{\nu}) = q^h_x(p^h(\tau,\tilde{p}^f);\vec{\nu}^h) + q^f_x(\tilde{p}^f;\vec{\nu}^f), \tag{1.13}$$

where supply and demand are given by Equations (1.4), (1.6), and (1.10).[12] The equilibrium foreign price is a thus a function of Home's tariff and the allocation of GVC inputs: $\tilde{p}^f \equiv \tilde{p}^f(\tau;\vec{\nu})$.

1.2 The Optimal Tariff

The Home government chooses the tariff to maximize aggregate indirect utility, subject to optimal consumer and producer responses and market clearing conditions. Suppressing exogenous arguments, the optimal tariff (τ^o) is given by:

$$\begin{aligned} \tau^o = \arg\max_{\tau} \quad & V\big(p^h, I(p^h,p^f)\big) \\ \text{s.t.} \quad & p^h = \tau p^f = \tilde{p}^h(\tau) \quad \text{and} \quad p^f = \tilde{p}^f(\tau). \end{aligned} \tag{1.14}$$

The associated first order condition is:

$$V_\tau = V_p \frac{d\tilde{p}^h}{d\tau} + V_I \left\{ \frac{\partial I(p^h,p^f)}{\partial p^h}\frac{d\tilde{p}^h}{d\tau} + \frac{\partial I(p^h,p^f)}{\partial p^f}\frac{d\tilde{p}^f}{d\tau} \right\} = 0, \tag{1.15}$$

where $V_p \equiv \frac{\partial V(p^h,I^h)}{\partial p^h}$ and $V_I \equiv \frac{\partial V(p^h,I^h)}{\partial I^h}$.[13] Applying Roy's identity, using the derivatives of Equation (1.10) with respect to p^h and p^f, and collecting terms yields:

$$V_\tau = V_I \Bigg[\underbrace{(\tau^o - 1)p^f \frac{dM_x}{d\tau} - M_x \frac{d\tilde{p}^f}{d\tau}}_{\text{terms-of-trade motive}} - \frac{dFVA^h}{d\tau} + \frac{dDVA_h}{d\tau} \Bigg] = 0. \tag{1.16}$$

The expression above the underbrace captures the standard terms-of-trade cost-shifting motive [Johnson (1951-1952)]. The remaining two terms in (1.16) reflect the influence of GVC linkages on the optimal tariff: tariffs change the income accruing to Foreign GVC inputs in Home production (FVA^h) and Home GVC inputs used in Foreign production (DVA_h).

[12] Combining (1.6) and (1.10) yields: $d^c(p^c, I^c(\vec{p};\vec{\nu})) = d^c(\vec{p};\vec{\nu}), c \in \{h,f\}$, as written in (1.13). By Walras' law, the market for y also clears according to the national balanced budget conditions embedded in (1.7).

[13] The assumption made above to rule out the Metzler and Lerner paradoxes ($\frac{d\tilde{p}^f}{d\tau} \leq 0 \leq \frac{d\tilde{p}^h}{d\tau}$) ensures that the second order condition is satisfied for small tariffs.

With an eye toward empirical applications, we decompose $\frac{dFVA^h}{d\tau}$ and $\frac{dDVA_h}{d\tau}$ as follows:

$$\frac{dFVA^h}{d\tau} = \frac{dFVA^h}{dp^h}\frac{d\tilde{p}^h}{d\tau} = \underbrace{\left(\frac{dr_f^h}{dp^h}\frac{p^h}{r_f^h}\right)}_{\equiv \varepsilon_f^{rh}>0}\underset{+}{\frac{r_f^h \nu_f^h}{p^h}}\underset{+}{\frac{dp^h}{d\tau}} = \varepsilon_f^{rh}\frac{FVA^h}{p^h}\frac{d\tilde{p}^h}{d\tau} > 0, \tag{1.17}$$

$$\frac{dDVA_h}{d\tau} = \frac{dDVA_h}{dp^f}\frac{d\tilde{p}^f}{d\tau} = \underbrace{\left(\frac{dr_h^f}{dp^f}\frac{p^f}{r_h^f}\right)}_{\equiv \varepsilon_h^{rf}>0}\underset{+}{\frac{r_h^f \nu_h^f}{p^f}}\underset{-}{\frac{dp^f}{d\tau}} = \varepsilon_h^{rf}\frac{DVA_h}{p^f}\frac{d\tilde{p}^f}{d\tau} < 0. \tag{1.18}$$

Here ε_f^{rh} and ε_h^{rf} represent the elasticity of the return to GVC inputs with respect to changes in the local final goods price in Home and Foreign, respectively.

Substituting Equations (1.17) and (1.18) into the first order condition, applying the market-clearing condition, and isolating τ^o, we arrive at an implicit function that defines the optimal tariff:

$$\tau^o = 1 + \frac{1}{\epsilon_x^f}\left(1 - \varepsilon_h^{rf}\frac{DVA_h}{p^f E_x^f} - \varepsilon_f^{rh}\frac{FVA^h}{p^h E_x^f}\frac{1}{|\lambda|}\right), \tag{1.19}$$

where $\lambda \equiv \frac{d\tilde{p}^f}{d\tau} \Big/ \frac{d\tilde{p}^h}{d\tau} < 0$ and $\epsilon_x^f > 0$ is foreign export supply elasticity.[14]

This expression echoes the canonical solution for the optimal tariff of a national-income maximizing government, as in Johnson (1951-1952), but it is modified to incorporate GVC linkages. Specifically, the inverse export supply elasticity captures the terms-of-trade motive for tariff setting: When foreign export supply is less elastic, the Home government will set a higher tariff to exploit its market power. GVC linkages alter that motive in two ways.

First, the use of Home GVC inputs in foreign production serves to dampen the terms-of-trade cost-shifting motive. The reason is that $\frac{dDVA_h}{d\tau} = \frac{dDVA_h}{dp^f}\frac{d\tilde{p}^f}{d\tau} < 0$: an increase in Home's tariff, which lowers the price of foreign-produced final goods, is passed back through the value chain (in the form of lower returns) to Home's suppliers of GVC inputs used in foreign production. In effect, GVC links lead the large importing country to internalize some of the terms-of-trade externality. As in Equation (1.18), the strength of this mechanism is increasing with the pass-through elasticity from foreign final goods prices to domestic GVC inputs (ε_h^{rf}) and the magnitude of the GVC input trade (DVA_h).

Second, the use of Foreign GVC inputs in Home production gives rise to a second, distinct spillover channel. An increase in Home's tariff raises income earned by those foreign factors of production, $\frac{dFVA^h}{d\tau} = \frac{dFVA}{dp^h}\frac{d\tilde{p}^h}{d\tau} > 0$: Home's tariff raises the price received by domestic

[14] We define the export supply elasticity to include income effects from changes in Foreign GVC income: $\epsilon_x^f \equiv \epsilon_x^f(\tau, \vec{\nu}) = \frac{p^f}{E_x^f}\frac{dE_x^f(p^f,I^f)}{dp^f} + \frac{\partial E_x^f(p^f,I^f)}{\partial I^f}\frac{dFVA}{dp^h}\frac{p^f}{\lambda E_x^f}$. The first term is the direct analog to the trade elasticity in conventional models without GVC income.

import-competing final goods producers, at the expense of domestic consumers. When Home production uses foreign-sourced GVC inputs, some of the protectionist rents generated by this price increase are passed back upstream to Foreign input suppliers. This FVA pass-through mechanism – from Home's tariff to its domestic price, and from the domestic price to the return to Foreign GVC inputs embedded in domestic production – constitutes a distinct domestic-price externality that also serves to drive down the optimal tariff, all else equal. The strength of the mechanism is again increasing with the pass-through elasticity ε_f^{rh} and the magnitude of GVC input trade (FVA^h).

In Equation (1.19), we further note that the trade volume (E_x^f) and the elasticity of trade (ϵ_x^f) scale the (direct) relationship between the GVC terms and the optimal tariff. This is because the trade volume influences the strength of GVC linkages as a counterweight to the terms-of-trade motive. All else equal, higher trade volumes magnify the terms-of-trade motive relative to the (direct) trade-liberalizing influence GVC linkages.

The optimal tariff expression in Equation (1.19) offers valuable insights into the equilibrium relationship between the tariff level and the elasticity of trade, trade values, pass-through elasticities, and GVC income. Further, by linking optimal tariffs to potentially-observable GVC income linkages, it will serve to structure our empirical investigation to follow. Before pushing forward in that direction, we pause to present comparative statics results that describe how optimal tariffs change in response to exogenous changes in GVCs.

1.3 Comparative Statics

In this section, we characterize the impact of exogenous changes in the endowment of GVC inputs on the optimal tariff. Specifically, consider an increase in either the quantity of Home GVC inputs used in Foreign production (ν_h^f), or the quantity of Foreign GVC inputs used in Home production (ν_f^h). These changes will lead Home's optimal tariff to decline, as long as their direct effects outweigh their indirect effects. The following proposition formalizes this statement.

Proposition 1. *The optimal tariff is decreasing with GVC inputs ν_h^f [ν_f^h] if and only if the (unambiguously negative) direct first-order influence of ν_h^f [ν_f^h] on the optimal tariff outweighs any indirect second-order influence of ν_h^f [ν_f^h] on the tariff via changes in trade volumes, trade elasticity, and pass-through rates; i.e. if and only if Condition 1 [2] is satisfied.*

Condition 1. *Necessary and sufficient condition for* $\frac{d\tau^o}{d\nu_h^f} < 0$*:*

$$\left[\underbrace{\frac{dr_h^f}{dp^f}}_{\text{direct effect}(+)} + \underbrace{\frac{d}{d\nu_h^f}\left(\frac{dr_h^f}{dp^f}\right)\nu_h^f + \frac{d}{d\nu_h^f}\left(\frac{dr_f^h}{dp^h}\frac{1}{|\lambda|}\right)\nu_f^h}_{\text{(indirect) changes in pass-through rates (+/-)}} + \underbrace{\frac{d}{d\nu_h^f}\Big((\tau^o - 1)E_x^f(\epsilon_x^f - 1)\Big)}_{\text{(indirect) change in terms of trade motive (+/-)}} \right]\Bigg|_{\tau^o} > 0.$$

Condition 2. *Necessary and sufficient condition for* $\frac{d\tau^o}{d\nu_f^h} < 0$*:*

$$\left[\underbrace{\frac{dr_f^h}{dp^h}\frac{1}{|\lambda|}}_{\text{direct effect}(+)} + \underbrace{\frac{d}{d\nu_f^h}\left(\frac{dr_h^f}{dp^f}\right)\nu_h^f + \frac{d}{d\nu_f^h}\left(\frac{dr_f^h}{dp^h}\frac{1}{|\lambda|}\right)\nu_f^h}_{\text{(indirect) changes in pass-through rates (+/-)}} + \underbrace{\frac{d}{d\nu_f^h}\Big((\tau^o - 1)E_x^f(\epsilon_x^f - 1)\Big)}_{\text{(indirect) change in terms of trade motive (+/-)}} \right]\Bigg|_{\tau^o} > 0.$$

[**Proof in Appendix A.2**] These conditions are satisfied, for example, in a setting with iso-elastic trade and constant pass-through from final goods prices to returns to GVC inputs. We provide a functional form example, with quadratic utility and Cobb-Douglas production, that serves to illustrate the proposition in Appendix A.3.

The following corollary, which follows directly from Equation (1.19), offers another useful benchmark.

Corollary 1.1. *Compare an equilibrium with GVC input trade, in which* $\hat{\nu}_h^f, \hat{\nu}_f^h > 0$*, against a no-GVC benchmark, in which* $\bar{\nu}_h^f, \bar{\nu}_f^h \equiv 0$*. If* $\epsilon_x^f(\tau; \hat{\nu}_h^f, \hat{\nu}_f^h) \geq \epsilon_x^f(\tau; \bar{\nu}_h^f, \bar{\nu}_f^h)\ \forall\ \tau$ *then* $\hat{\tau}^o < \bar{\tau}^o$*.*

In other words, a sufficient (but not necessary) condition for the introduction of trade in GVC inputs to reduce the optimal tariff is that introducing GVC input trade does not increase the importing country's leverage to depress foreign prices by reducing the elasticity of export supply.

1.4 The Optimal Tariff with Endogenous GVCs

Thus far, we have analyzed optimal tariffs under the assumption that GVC inputs are specific factors. We now relax that assumption, allowing producers to re-optimize their use of GVC inputs in response to price changes. To distinguish effects that operate through prices versus quantities, we assume that the substitutability of GVC inputs across destinations is limited, so that the equilibrium returns to those inputs may differ across countries. Beyond this, we are agnostic about the underlying determinants of GVC structure; we assume only that an increase in the local price of the (non-numéraire) final good weakly increases the return to, and the use of, the GVC inputs used in its production. This assumption (formalized in

Appendix A.4) is a natural extension the specific factors case. To streamline analysis, we also adopt quasi-linear preferences.

As before, Home's national income is given by Equation (1.10), and the government maximizes aggregate indirect utility subject to the arbitrage and market clearing conditions described in Equation (1.14). The optimal tariff takes the form:

$$\tau^o = 1 + \frac{1}{\epsilon_x^f}\left(1 - (\tilde{\varepsilon}_h^{rf} + \tilde{\varepsilon}_h^{\nu f})\frac{DVA_h}{p^f E_x^f} - (\tilde{\varepsilon}_f^{rh} + \tilde{\varepsilon}_f^{\nu h})\frac{FVA^h}{p^h E_x^f} + \eta\right), \tag{1.20}$$

where ϵ_x^f is the foreign export supply elasticity for final goods (holding $\vec{\nu}$ fixed), η captures the impact of changes in final goods trade as a result of the endogenous change in input use, and the $\tilde{\varepsilon}$s are analogs to the pass-through elasticity terms in the baseline specific factors model. See Appendix A.4 for details of the derivation and precise definition of these terms.

The first substantive difference between this expression and the corresponding optimal tariff in the specific factors model (Equation (1.19)) is that the pass-through terms attached to DVA and FVA now allow for potential changes in both the *prices* (via $\tilde{\varepsilon}^r$) and *quantities* (via $\tilde{\varepsilon}^\nu$) of GVC inputs used in response to tariff changes. In the specific factors setting, the $\tilde{\varepsilon}_j^{rc}$ terms were unambiguously positive, and the $\tilde{\varepsilon}_j^{\nu c}$ terms were identically zero. In this more general model, the signs of $\tilde{\varepsilon}_h^{rf} + \tilde{\varepsilon}_h^{\nu f}$ and $\tilde{\varepsilon}_f^{rh} + \tilde{\varepsilon}_f^{\nu h}$ depend on the relative responsiveness of GVC income to changes in local prices versus changes in prices abroad. Concretely, $\tilde{\varepsilon}_h^{rf} + \tilde{\varepsilon}_h^{\nu f} > 0$ as long as the decrease in the foreign final goods price due to Home's tariff causes DVA to fall more than the potential increase in DVA associated with higher final goods prices at home. Likewise, $\tilde{\varepsilon}_f^{rh} + \tilde{\varepsilon}_f^{\nu h} > 0$ as long as the increase in FVA induced by the increased price of the final good at Home outweighs any potential decline in FVA due to the decline in the foreign price of the final good. Sufficient international segmentation in input markets will ensure that these conditions hold.

The second difference is that there is a new term, η, in the optimal tariff, which captures the impact of changes in GVC input use on final goods production patterns. Notably, some or all of η may cancel with the endogenous input reallocation components of the DVA and FVA terms (the $\tilde{\varepsilon}^\nu$s); how much depends on assumptions regarding the underlying market structure governing input use. For example, if GVC inputs are paid the value of their marginal product, then as frictions in input markets fall to zero, η will cancel the $\tilde{\varepsilon}^\nu$ terms, leaving just the price-pass through mechanisms (the $\tilde{\varepsilon}^r$s). (See Lemma 2 in Appendix A.4.)

In summary, although a more flexible production structure introduces additional adjustment channels, these channels can still be summarized in terms of pass-through elasticities, as in the specific-factors model. And although the behavior of the pass-through elasticity terms depends on particular model assumptions, the *sign* of these pass-through terms will be positive as long as the income associated with a given GVC input is more responsive to the local price where the input is used than it is to prices elsewhere. Thus, the basic predictions for how GVCs influence tariff setting are robust to relaxation of the specific-factors assumption, as long as Home's GVC income is decreasing in its tariffs. Accordingly, our predictions would obtain in many models of global value chains.

1.5 Input Tariffs

In analyzing tariffs for final goods, we have abstracted from the simultaneous analysis of input tariffs. We pause here to explain why it is both reasonable and prudent to do so.

We begin by introducing input tariffs into the benchmark model. We show that an exogenous tax on Home's foreign-sourced GVC inputs attenuates the impact of FVA on the optimal final goods tariff, but does not change the key directional predictions of the model. We then consider endogenous input tariffs. In the benchmark specific factors model, we note that endogenous input tariffs are both uninteresting and unrealistic: the optimal tariff is set to extract all rents accruing to foreign GVC inputs. Then, we briefly discuss input tariffs in models with endogenous GVC input use. We argue that general predictions for how input tariffs depend on GVC linkages are elusive, in contrast to our results for final goods tariffs.

1.5.1 Input Tariffs in the Benchmark Model

Returning to the specific factors model in Section 1.1, suppose that Home levies an exogenous, ad-valorem tax $g \in [0, 1]$ on the foreign-sourced GVC inputs used in domestic production, ν_f^h, applied to the local price of these inputs, r_f^h. All other assumptions and model structure are the same.

As before, national income is given by Equation (1.10), but tariff revenue is now:

$$R^h = (p^h - p^f)M_x^h + g r_f^h \nu_f^h. \tag{1.21}$$

Maximizing aggregate indirect utility subject to market clearing conditions, the first order condition of Home's optimal tariff problem is given by:

$$V_\tau = V_I \left[(\tau^o - 1)p^f \frac{dM_x}{d\tau} - M_x \frac{d\tilde{p}^f}{d\tau} - (1-g)\frac{dFVA^h}{d\tau} + \frac{dDVA_h}{d\tau} \right] = 0. \tag{1.22}$$

Applying the market-clearing condition, using the same tariff decompositions in Equations

(1.17) and (1.18), and isolating τ^o, yields the augmented optimal tariff expression:

$$\tau^o = 1 + \frac{1}{\epsilon_x^f}\left(1 - \varepsilon_h^{rf}\frac{DVA_h}{p^f E_x^f} - (1-g)\varepsilon_f^{rh}\frac{FVA^h}{p^h E_x^f}\frac{1}{|\lambda|}\right). \tag{1.23}$$

The input tariff enters this optimal (final good) tariff expression in two ways. First, the input tariff directly weakens the link between FVA and the optimal tariff: all else equal, higher input tariffs allow the Home government to capture more of the protectionist rents associated with final goods tariffs, dampening the tariff-liberalizing influence of FVA on trade protection. Additionally, input tariffs may enter the optimal final goods tariff indirectly, by changing the underlying mapping from final goods prices to input prices (and thus the ε_f^{rh} term). Crucially, neither of these potential effects of input tariffs on final goods tariffs changes the directional predictions of the model. The upshot: introducing arbitrary input tariffs does not change the basic structure of the optimal final goods tariff, or our central finding that GVCs erode mercantilist motives for trade protection in final goods.[15]

1.5.2 Endogenous Input Tariffs

We now take up the question of the optimal tariff on inputs: what is the Home country's optimal tax (g^o) applied to foreign-sourced GVC inputs used in Home production? Although the structure of this problem is similar to the optimal tariff problem for final goods, the nature of the solution is qualitatively different. The directional relationship between input tariffs and GVCs is fundamentally model-dependent, in a way that the relationship between final goods tariffs and GVCs is not.

To begin, notice that allowing for an endogenous input tariff in the context of our benchmark specific-factors setting is trivial. If GVC inputs are fixed, the Home government would use input tariffs to extract all rents associated with foreign-supplied inputs. The optimal input tariff is thus a corner solution at $g^o = 1$. The final goods tariff would still be given by Equation (1.23), but with $g = 1$, the optimal tariff would not depend on FVA. Moreover, if the foreign government also used an optimal import tariff to extract all of Home's GVC income (DVA), then Home's optimal final good tariff would collapse to the familiar inverse elasticity rule. This makes sense: if input tariffs allow governments to completely expropriate the rents associated with GVC trade, governments will behave as if all factors of production used in local production are their own. This result is as counterfactual as it is obvious; in practice, tariffs on intermediate inputs are systematically lower than final goods

[15]Adding an exogenous input tax to the model with endogenous GVC input use (Section 1.4) yields the general equilibrium analog to Equation (1.23). See Appendix A.5. The qualitative conclusions are the same.

tariffs, and they are also low in absolute terms [Bown and Crowley (2016); Shapiro (2021)].

Meaningful analysis of endogenous input tariffs thus requires a general equilibrium setting in which GVC inputs respond endogenously to prices. Drawing on the framework from Section 1.4, we analyze the optimal input tariff in Appendix A.5. For a given final good tariff τ, the first order condition for the optimal input tariff is given by:

$$V_g = V_I \left[(\tau-1)p^f \frac{dM_x}{dg} - M_x \frac{d\tilde{p}^f}{dg} + p^h \nabla_{\vec{\nu}} q_x^h \cdot D_g \vec{\nu} + \frac{dDVA_h}{dg} - (1-g^o)\frac{dFVA^h}{dg} + FVA \right] = 0 \quad (1.24)$$

On examination, it is clear that optimal input tariffs, like final goods tariffs, will be characterized by an (own) inverse elasticity rule: the greater the elasticity of foreign-sourced GVC inputs, the lower the optimal input tax on those inputs, all else equal. As is the case for final goods tariffs, this inverse elasticity rule will be moderated by GVC linkages, reflected in a series of cross-elasticities: how the input tariff affects the pattern of input use and thus final goods production, prices, trade and the associated tax revenue, and DVA.

The relationship between GVCs and optimal input tariffs depends on the structure of these cross-elasticities. Unfortunately, there is no obvious disciplining device for placing bounds on them, which implies that one cannot easily sign the directional relationship between input tariffs and GVC linkages. Even in our simple setting, specific assumptions – whether GVC inputs are complements or substitutes in production, or whether there are differences in productivity across countries (so that a reallocation of inputs across countries would change the global supply of the final good) – would be needed to pin down definitive results. We refer the reader to Antràs and Chor (2022) for further discussion of the complexity of these issues.

A signature strength of our theoretical approach to evaluating final goods tariffs is that it side-steps hard-to-quantify production details, yet yields predictions that are amenable to direct econometric investigation. Extending the analysis to input tariffs defeats this advantage. Thus, we set aside input tariffs for the remainder of the paper to focus on the relationship between GVC linkages and trade protection for final goods only.

2 Theory to Data

In this section, we modify the benchmark model introduced in Section 1 to allow for many countries and sectors, as well as political economy considerations. We use this extended framework to motivate a regression-based empirical strategy that sheds light on how tariff preferences are correlated with GVC income in the data.

2.1 Many-Country, Many-Good Model with Political Economy

Building on Section 1.1, suppose the 'home' country (indexed by h) now produces, consumes, and trades S final goods (in set $\mathcal{S}$) plus one freely-traded homogeneous numéraire good (indexed by 0) with C trading partners (in set $\mathcal{C}$). Beyond the increase in the number of goods and countries, there are two substantive changes in the model. We discuss them briefly here, and refer the reader to Appendix A.6 for a complete exposition.

First, we adopt quasi-linear preferences, as in Grossman and Helpman (1994):

$$U^c(d_0^h, \vec{d}_s^{\,h}) = d_0^h + \sum_{s \in \mathcal{S}} u_s(d_s^h) \qquad \forall h \in \mathcal{C}, \tag{2.1}$$

where $\vec{d}_s^{\,h}$ is a vector of country h's consumption of each non-numéraire good, and sub-utility over each non-numéraire good, $u_s(\cdot)$, is increasing, continuously differentiable, and strictly concave. We also assume that the representative consumer has sufficient income to consume a strictly positive quantity of the numéraire.

Second, we introduce political economy motivations for policy. Following Helpman (1997) and Ludema and Mayda (2013), we assume that the Home government maximizes the sum of aggregate indirect utility and a set of "special interest factors" associated with the quasi-rents from production in different final goods sectors:

$$G^h = V^h + \sum_{s \in \mathcal{S}} [\delta_s^{DPE} \pi_s^h + \delta_s^{DVA} DVA_{sh} + \delta_s^{FVA} FVA_s^h], \tag{2.2}$$

where V^h is Home's (endogenous) aggregate indirect utility, π_s^h is the residual profit from Home's production of good s, $DVA_{sh} = \sum_{j \neq h} r_{sh}^j(p_s^j; \vec{\nu}_s^j)\nu_{sh}^j$ is the return to Home's GVC inputs used in foreign production of good s, and $FVA_s^h = \sum_{j \neq h} r_{sj}^h(p_s^h; \vec{\nu}_s^h)\nu_{sj}^h$ is the total return to foreign GVC inputs used in Home's production of good s.

The parameters $\delta_s^{DPE}, \delta_s^{FVA}$, and δ_s^{DVA} are exogenous political economy weights. The parameter δ_s^{DPE} captures any additional consideration that the Home government affords to rents earned in domestic final goods production (π_s^h). Similarly, δ_s^{DVA} reflects any extra political value that the Home government places on the returns to Home's GVC inputs used in foreign final goods production (DVA_{sh}).[16] Finally, δ_s^{FVA} represents the political weight (if any) given to foreign GVC inputs used in Home's production (FVA_s^h). We do not impose *a priori* restrictions on these weights, but standard arguments would imply positive values for politically active constituencies [Grossman and Helpman (1994)].

[16] Since both $\sum_s \pi_s^h$ and $\sum_s DVA_{sh}$ are included in Home's national income, they are already included in V^h with a weight of 1; thus, δ_s^{DPE} and δ_s^{DVA} capture any *additional* weight afforded to these rents by the Home government, above and beyond their direct contribution to aggregate welfare.

Endowments, technology, and remaining model structure are the same as in the 2x2 model, with straightforward extensions to the multi-country, multi-industry setting. We allow arbitrary exogenous tariffs or other trade barriers between Home's trading partners, but require that prices obey a set of SC no-arbitrage conditions: $p_s^h \leq \tau_{sc}^h p_s^c, \forall c \neq h \in \mathcal{C}, s \in \mathcal{S}$, which hold with equality when there is trade. Equilibrium prices are then pinned down by a set of S market clearing conditions that ensure global demand equals global supply for each non-numéraire good: $\sum_{c\in\mathcal{C}} d_s^c(\tilde{p}_s^c) = \sum_{c\in\mathcal{C}} q_s^c(\tilde{p}_s^c; \vec{\nu}_s^c)$ for all $s \in \mathcal{S}$. Balanced budget conditions for each country clear the market for the numéraire.

Politically-Motivated Bilateral Tariffs The Home government chooses its politically-optimal bilateral tariffs ($\{\tau_{xj}^h\}_{j\neq h}$) to maximize Equation (2.2), subject to balanced budget, market clearing, and no arbitrage constraints, taking other countries' policies as given. Referring to Appendix A.6 for the derivation, we present the implicit solution for Home's optimal tariffs (analogous to Equation (1.19)) here:

$$\tau_{xj}^h = 1 + \frac{1}{\epsilon_{xh}^j}\left(1 + \frac{\delta_x^{DPE}}{|\lambda_{xj}^h|}\frac{p_x^h q_x^h}{p_x^h E_{xh}^j} - (1+\delta_x^{DVA})\varepsilon_{xh}^{rj}\frac{DVA_{xh}^j}{p_x^j E_{xh}^j} - \frac{(1-\delta_{x*}^{FVA})\varepsilon_{x*}^{rh}}{|\lambda_{xj}^h|}\frac{FVA_x^h}{p_x^h E_{xh}^j} - \tilde{\Omega}_{xj}\right). \quad (2.3)$$

Outside the parentheses, $\epsilon_{xh}^j \equiv \frac{dE_{xh}^j}{dp_x^j}\frac{p_x^j}{E_{xh}^j} > 0$ is the export supply elasticity for x imported by h from j. Inside the parentheses, q_x^h is the quantity of good x produced in h, and E_{xh}^j is the quantity of country j's exports of x to h. DVA_{sh}^j is the return to GVC inputs from h used by j in industry s, given by $r_{sh}^j(p_s^j; \vec{\nu}_s^j)\nu_{sh}^j$, and FVA_s^h is defined above. ε_{xh}^{rj} is the elasticity of the return to h's GVC inputs used by industry x in country j with respect to p_x^j, and ε_{x*}^{rh} is the elasticity of the return to (all) foreign GVC inputs used by industry x in home with respect to p_x^h. Finally, $\lambda_{xj}^h \equiv \frac{d\tilde{p}_x^j}{d\tau_{xj}^h} / \frac{d\tilde{p}_x^h}{d\tau_{xj}^h} < 0$, and $\tilde{\Omega}_{xj}$ captures potential third-country effects of trade diversion (see the appendix for the full characterization of this term).

As compared to Equation (1.19), there are several new features in Equation (2.3). First, there is a term that captures how a politically-motivated government trades off the interests of import-competing domestic producers against social welfare, which depends both on the inverse import penetration ratio ($p_x^h q_x^h / p_x^h E_{xh}^j$) and the parameter δ_s^{DPE}. All else equal, the government will offer more generous tariff protection when import penetration (and thus the social cost of trade protection) is low. Such protection-for-sale influences have been shown to be empirically important determinants of tariff policy [Goldberg and Maggi (1999); Gawande and Bandyopadhyay (2000)].

Second, political economy motivations may also reinforce or attenuate the influence of GVCs. If the government affords additional political consideration to the interests of its upstream suppliers of GVC inputs, as in $\delta_x^{DVA} > 0$, then the trade-liberalizing potential of DVA will be stronger, all else equal. Conversely, if the government responds to the interests of the foreign GVC input suppliers to its downstream producers, as in $\delta_x^{FVA} > 0$, the trade-liberalizing influence of FVA will be attenuated. Nonetheless, as long as domestic consumer concerns dominate the interests of foreign suppliers of GVC inputs ($\delta_x^{FVA} < 1$), bilateral tariffs decrease in FVA.

Third, notice that τ_{xj}^h depends on the *bilateral* value of Home's GVC income from foreign production (DVA_{xh}^j) and the *multilateral* value of foreign GVC income from home production (FVA_x^h). The intuition for the multilateral role of FVA is that any increase in the local price of x (p_x^h) is necessarily passed on to *all* foreign suppliers of GVC inputs, not just those from country j.[17] In contrast, τ_{xj}^h depends on the bilateral value of domestic content in foreign production (DVA_{xh}^j), because the terms-of-trade externality is fundamentally bilateral. As the home country uses its tariff to depress the foreign output price, it cares about the repercussions only for its own input suppliers, not for third country input suppliers.

Trade Policy Institutions In practice, governments set bilateral applied tariffs subject to constraints imposed by trade policy institutions. One important constraint is the most-favored-nation (MFN) rule, which dictates that WTO members may not discriminate in their applied tariffs across their WTO-member trading partners, but for defined exceptions specified in the GATT's Article XXIV and Enabling Clause. Further, while countries may offer lower-than-MFN preferential tariffs to selected WTO-partners under these exceptions, they may not impose higher-than-MFN discriminatory tariffs. As a result, MFN tariff rates effectively serve as an upper bound on applied bilateral tariffs.

To incorporate this constraint, we define the government's applied tariff problem, as distinct from its optimal tariff problem. The government sets applied tariffs $\{\tau_{xj}^h\}$ to maximize is objective function in Equation (2.2) subject to to the additional constraint that $\tau_{xj}^h \leq \tau_x^{h,\text{MFN}}$, where $\tau_x^{h,\text{MFN}}$ denotes (one plus) its MFN tariff, along with balanced budget, market clearing, and no-arbitrage conditions. Following Grossman and Helpman (1995*a*), we take MFN tariffs as given when analyzing politically-optimal applied bilateral tariffs.[18] With slight modifications to accommodate the constraint, the logic of the constrained optimal tar-

[17] In deriving Equation 2.3, we impose a common pass-through elasticity across foreign input suppliers (ε_{x*}^{rh}), reflecting this multilateral argument and how we have modeled returns to specific GVC inputs. Relaxing this assumption, one would replace FVA_x^h with an elasticity-weighted average of bilateral foreign GVC income.

[18] Grossman and Helpman (1995*a*) appeal to GATT Article XXIV to justify this assumption, which prohibits countries that adopt bilateral agreements from raising their external (MFN) tariffs. Further, MFN tariffs for many countries were set under the Uruguay Round, which concluded before the start of the period for which we examine data below.

iff continues to conform to that in Equation (2.3), so we do not provide a full analytical treatment of it here. We will solve for constrained optimal tariffs in numerical analysis of the model, however.

With an eye toward data, applied tariffs are bound above by each country's MFN tariff rate. That is, countries offer tariff preferences, given by $t^{h,applied}_{xjt} - t^{h,MFN}_{xt}$, where $t^{h,applied}_{xjt}$ is the observed bilateral tariff rate. The MFN rule implies that these preferences take on negative values, censored above by zero. We will account for this censoring in the empirical analysis below.

In a different vein, while most bilateral tariff preferences are unilateral, some are granted via bilateral or regional trade agreements (RTAs), under which governments may cooperate via negotiation in setting tariffs. Theoretically, these negotiations may mitigate or even eliminate cost-shifting externalities [Grossman and Helpman (1995*b*), Bagwell and Staiger (1999)]. As a result, cooperation between RTA members could change the relationship between value-added content and applied tariffs set within RTAs. In the empirical analysis that follows, some specifications will control for whether country pairs have an RTA in force, and then we examine how value-added content influences tariffs set under different preference regimes in Appendix B.

2.2 Empirical Strategy

To guide our empirical investigation, we take a linear approximation of Equation (2.3) around a baseline equilibrium in which there are no GVC linkages ($\vec{\nu} = 0$, such that $DVA^j_{xh} = 0$ and $FVA^h_x = 0 \ \forall x \in \mathcal{S}, j \in \mathcal{C}$). The result is:

$$t^h_{xj} = \frac{1}{\bar{\epsilon}^j_{xh}} + \gamma^{IP}_{xhj}\left(\frac{FG^h_{xt}}{\bar{p}^h_x \bar{E}^j_{xh}}\right) + \gamma^{DVA}_{xhj}\left(\frac{DVA^j_{xh}}{\bar{p}^j_x \bar{E}^j_{xh}}\right) + \gamma^{FVA}_{xh}\left(\frac{FVA^h_x}{\bar{p}^h_x \bar{E}^j_{xh}}\right) + \omega_{xhj}, \tag{2.4}$$

where $t^h_{xj} \equiv \tau^h_{xj} - 1$, bars denote equilibrium objects evaluated at the point of approximation, $FG^h_{xt} \equiv p^h_x q^h_x$, $\gamma^{IP}_{xhj} \equiv \frac{\delta^{PE}_x}{\bar{\epsilon}^j_{xh}|\bar{\lambda}^h_{xj}|}$, $\gamma^{DVA}_{xhj} \equiv -\frac{(1+\delta^{DVA}_x)\bar{\varepsilon}^{rj}_{xh}}{\bar{\epsilon}^j_{xh}}$, $\gamma^{FVA}_{xhj} \equiv -\frac{(1-\delta^{FVA}_x)\bar{\varepsilon}^{rh}_{x*}}{\bar{\epsilon}^j_{xh}|\bar{\lambda}^h_{xj}|}$, and ω_{xhj} includes approximation errors and potential trade diversion effects.[19]

This expression is a mix of observable variables and parameters. The three key observables are the levels of final goods production (FG^h_{xt}), foreign GVC income generated by home production (FVA^h_{xt}), and domestic GVC income from foreign production (DVA^j_{xht}). Each of these is measurable in our data, with the value-added content of final goods as a

[19] $\omega_{xhj} \equiv u_{xhf} - \tilde{\Omega}_{xj}$, where u_{xhf} is the approximation error and $\tilde{\Omega}_{xj}$ captures potential trade diversion effects. Third-country effects are generally ambiguous in sign, and plausibly small, especially for smaller trade partners that may generate little or no trade diversion.

proxy for GVC income. Each of these observables enters Equation (2.4) as a ratio, divided by bilateral imports in the no-GVC equilibrium, which we do not observe. We use realized bilateral imports as a proxy for these unobserved values to compute the ratios. Further, to address concerns about measurement error in the denominator, we take logs of these ratios to construct an estimating equation.[20]

The remaining parameters in Equation (2.4), including the inverse export supply elasticity ($1/\epsilon_{xj}^h$) and parameters in the γ-terms, are not directly observed. In prior empirical work on optimal tariffs, the inverse export supply elasticity has typically been assumed to be importer and industry specific.[21] Following this work, we make the same assumption and use importer-industry fixed effects to control for it.[22]

We treat the coefficients attached to the ratios in Equation (2.4) as parameters to be estimated. We start by assuming that each coefficient is homogeneous, as in $\gamma^{IP} = \gamma_{xhj}^{IP}$, $\gamma^{FVA} = \gamma_{xhj}^{FVA}$, and $\gamma^{DVA} = \gamma_{xhj}^{DVA}$. Building on this baseline, we then explore coefficient heterogeneity, along economically meaningful dimensions (discussed below).

Building on these refinements, plus discussion of the MFN rule above, we will embed Equation 2.4 within an empirical framework with censoring framework as follows:

$$t_{xjt}^{h,applied} - t_{xt}^{h,MFN} = \min\{t_{xjt}^h - t_{xt}^{h,MFN}, 0\}, \text{ with} \tag{2.5}$$

$$t_{xjt}^h - t_{xt}^{h,MFN} = \Phi_{xhjt} + \gamma^{FG} \ln\left(\frac{FG_{xt}^h}{IM_{xjt}^h}\right) + \gamma^{DVA} \ln\left(\frac{DVA_{xht}^j}{IM_{xjt}^h}\right) + \gamma^{FVA} \ln\left(\frac{FVA_{xt}^h}{IM_{xjt}^h}\right) + e_{xhjt}, \tag{2.6}$$

where $t_{xjt}^{h,applied}$ is the applied bilateral tariff (vis-a-vis partner i and $t_{xt}^{h,MFN}$ is the MFN tariff rate for country j.[23] In the subscripts, t denotes the time period. Further, IM_{xjt}^h is the value of bilateral imports by h of goods from sector x in country j, Φ_{xhjt} denotes the set of fixed effects (discussed below), and e_{xhjt} is a regression residual.

Equations 2.5 and 2.6 provide a regression framework for investigating data. To be clear, our initial aim is to document correlations in the data that are consistent with the

[20] The observed values the ratios are positively skewed, with a long right tail. This tail variation is difficult to reconcile with observed variation in tariffs. Compounding this issue, most ratios in the right tail of the data have small values for imports in the denominator, and imports are measured with error. As such, we suspect variation among observations in the right tail of the ratio distribution is largely driven by the measurement error itself. Taking logs serves to down-weight these observations.

[21] Among others, see Broda, Limão and Weinstein (2008), Ludema and Mayda (2013), and Nicita, Olarreaga and Silva (2018). Soderbery (2018) estimates bilateral trade elasticities and reports that almost three-quarters of the variation is explained by importer-product fixed effects.

[22] Because we include importer-year, importer-industry-year fixed effects, and exporter-industry-year fixed effects in various specifications, these also serve as additional controls for the export supply elasticity.

[23] Note that the dependent variable here is the tariff preference: $t_{xjt}^{h,applied} - t_{xt}^{h,MFN}$. A uniform reduction in all tariffs leaves this dependent variable unchanged. Further, if only MFN tariffs change, then tariff preferences would be compressed (i.e., the censoring bound is tightened). In OLS specifications that do not adjust for censoring, this compression pushes the coefficients toward zero, working against rejecting the null.

underlying theory. Noting the sign convention (more generous preferences are associated with *more negative* tariffs relative to MFN), theory predicts that $\gamma^{FG} > 0$ and $\gamma^{DVA} < 0$. With the prior that $\delta_x^{FVA} < 1$, then we expect $\gamma^{FVA} < 0$ as well. We will then use correlations of this sort to discipline parameters in quantitative analysis of the model below.

2.3 Evidence for Tariff Preferences

This section briefly describes sources and methods for compiling our data on bilateral tariffs and value-added content, with full details in Appendix B. We then discuss sources of variation in the bilateral tariff data and examine an illustrative case study to fix ideas.

2.3.1 Data

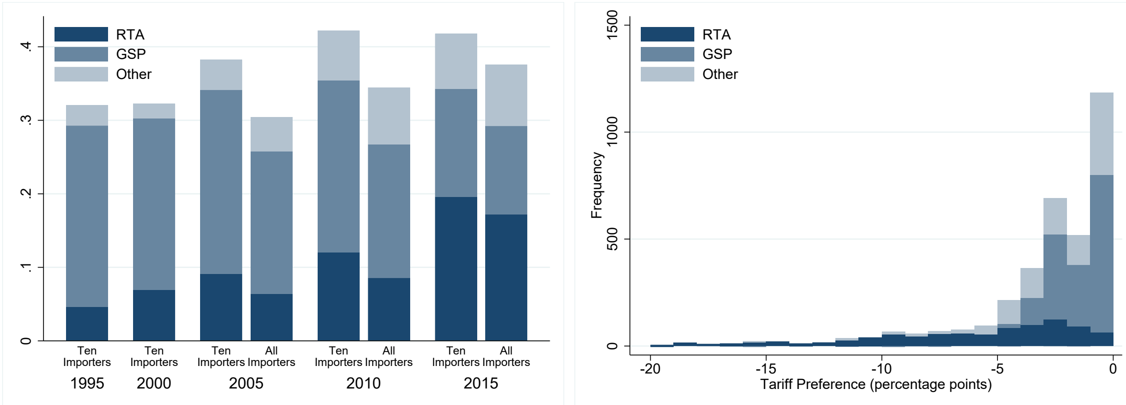
We construct bilateral, industry-level tariffs on final goods for five benchmark years: 1995, 2000, 2005, and 2010, and 2015. We start with product-level tariff schedules collected by UNCTAD (TRAINS) and the WTO, which we obtain via the World Bank's WITS website. Combining these sources and aggregating product lines yields a data set of bilateral tariffs at the Harmonized System (HS) 6-digit level. We then identify final goods (consumption and capital goods) in the data and link HS categories to WIOD industries using a correspondence developed by the OECD. We take simple averages across HS categories within each industry to measure industry-level applied bilateral and MFN tariffs.

To compute the national origin of value added contained in the final goods that each country produces, we use data from the World Input-Output Database (WIOD). The exact procedure, which is based on Los, Timmer and de Vries (2015), is described in the appendix. Combining data from two versions of the WIOD dataset, we are able to construct value-added contents for 14 "countries" (13 countries, plus the composite EU region) and 14 industries, which are listed in Table B1, that cover the 1995-2014 period.[24] We use value-added contents from 2014 in our analysis of tariffs in 2015.

Background on Tariff Preferences There are four main policy regimes under which countries grant tariff preferences. The first regime is the Generalized System of Preferences (GSP), under which developing countries receive preferential treatment from high-income importers. Each GSP-granting country unilaterally chooses the set of GSP-receiving countries to which and sectors in which it extends preferences, and these choices differ across GSP-granting countries and time. Free trade agreements and customs unions, authorized

[24] The countries are: Australia, Brazil, Canada, China, the European Union, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey, and the United States.

Figure 1: Tariff Preferences



(a) Tariff Preferences over Time

(b) Distribution of Tariff Preferences

Note: Sub-figure (a) reports the share of importer-exporter-industry cells (with non-zero MFN tariffs) that have preferential tariffs in place by year. Bars labelled ”Ten Importers” report data for a balanced panel of 10 importing countries with data available in all years. The histogram in Sub-figure (b) includes only observations for which applied bilateral tariffs are lower than MFN, and excludes observations with preferences < -20 for legibility. Bin width is set to 1 percentage point. In both figures, preferences are broken down by whether they occur under a regional trade agreement (RTA), the Generalized System of Preferences (GSP), or other preferential agreements.

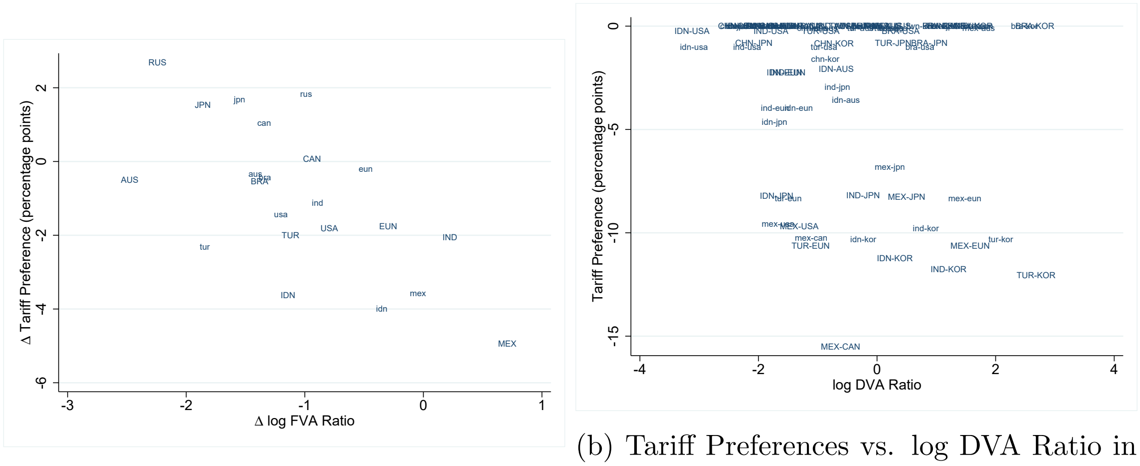
under WTO Article XXIV, are a second source of preferences. Despite their name, these agreements do not entail completely free trade: almost half of tariffs imposed on RTA partners are greater than zero in our data. The third source of preferences derives from trade agreements struck between developing countries under the auspices of the WTO's Enabling Clause, including so-called "Partial Scope Agreements." Lastly, a handful of idiosyncratic programs and one-off preferences constitute a fourth source of preferences in our data.

In Figure 1a, we track the prevalence of tariff preferences, by type. Tariff preferences are widespread: between 30-40% of all importer-exporter-industry cells have preferential tariffs. Moreover, the prevalence of tariff preferences has been increasing over time, rising by about ten percentage points from 1995 to 2015. At the same time, many preferences remain in place throughout our sample period, so cross-section variation (across sectors and trading partners) is an important dimension of the data. Lastly, the composition of preferences changes over time. RTAs and partial scope agreements have become more important sources of preferences over time, and they seem to progressively displace GSP preferences.

To illustrate the depth of preferences by regime, we plot the distribution of preferences in Figure 1b.[25] Since the magnitude of tariff preferences is generally larger under RTAs

[25]Conditional on receiving preferences, the mean (median) preference is about -3.2 (-2.2) percentage

Figure 2: Textiles, Leather, and Footwear Case Study



(a) Changes Tariff Preference vs. log FVA Ratio by Importer and Industry: 1995-2015

(b) Tariff Preferences vs. log DVA Ratio in 2015: High Income Importers & Emerging Market Exporters

Note: Sub-figure (a) plots changes in mean preferential tariffs by importer and industry, given by $\Delta_t \bar{t}^h_{xt} = \frac{1}{C-1}\sum_{j\neq h}\Delta_t\left(t^h_{xjt} - t^{h,MFN}_{xt}\right)$, against changes in the (multilateral) log FVA ratio, given by $\Delta \ln\left(\frac{FVA^h_{xt}}{IM^h_{xt}}\right)$, between 1995 and 2015. Sub-figure (b) plots $t^h_{xjt} - t^{h,MFN}_{xt}$ against $\ln\left(DVA^h_{xjt}/IM^h_{xjt}\right)$ for high income importers and emerging economies exporters in 2015. High income countries include Australia, Canada, the European Union, South Korea, and the United States. Emerging economies include the other 9 countries listed in Table B1, excluding Russia who faced economic sanctions in 2015. Labels indicate the importing country in Sub-figure (a) and the (ordered) exporter-importer pair in Sub-figure (b). In both figures, data for Textiles and Apparel (WIOD sector 4) is represented by capitalized labels, and data for Leather and Footwear (WIOD sector 5) is represented by lower case labels.

and partial scope agreements than the GSP, the rise of RTAs and displacement of non-RTA preferences over time represents a deepening of preferences over time.

Case Study: Textiles, Leather, and Footwear To illustrate variation in the data, we present a few figures for the Textiles, Leather, and Footwear sector, where value chain linkages are salient to policymakers, and the scope for and use of tariff discretion is high.

We start by examining the relationship between changes in FVA and average tariff preferences, within within importer-industry cells. Figure 2a plots the change in the mean tariff preference by importer and industry against the log changes in the ratio of foreign value added to imports between 1995 and 2015. There is a negative correlation in the data, consistent with theory: countries that saw comparatively more growth in FVA relative to gross imports also offered the greatest expansion of preferential market access to their trading

points, with a 10th-90th percentile range of $[-8.06, -0.09]$.

partners.[26]

Next we examine the relationship between DVA and bilateral tariff preferences, focusing on the cross-sectional dimension of the data. Honing in on a set of high-income importers buying goods from a set of emerging-market exporters, Figure 2b plots bilateral tariff preferences against the log ratio of DVA to bilateral imports, $\ln\left(DVA^i_{xjt}/IM^i_{xt}\right)$, in 2015. There is a negative correlation between applied tariffs and the DVA ratio overall, consistent with theory: high-income importers offered more generous tariff preferences for imports of Textiles, Leather, and Footwear to emerging-market trading partners that use more of their own GVC inputs. Note also that there is an obvious censoring problem in the figure, as there are many country pairs clustered at zero preference. This censoring likely biases the simple correlation toward zero, so we will adjust for it below.

2.3.2 Results

We present estimates of Equations (2.5)-(2.6) in Table 1. In all columns, the dependent variable is the observed tariff preference: $t^{h,applied}_{xjt} - t^{h,MFN}_{xt}$.[27] In columns (1)-(2), we present OLS results, ignoring censoring induced by the MFN rule. In columns (3)-(4), we present Tobit estimates that adjust for censoring. In all columns, we present standard errors that are clustered by importer-exporter pair.

We include importer-year and importer-industry fixed effects in columns (1) and (3). Here the coefficients attached to the ratio of FVA to bilateral imports (γ^{FVA}) and the import penetration ratio (γ^{IP}) are primarily identified by multilateral variation in average tariff preferences and foreign value added by importer and industry over time. In columns (2) and (4), we include importer-industry-year fixed effects, which remove multilateral variation in tariff preferences and regressors. In this specification, we are able to estimate the composite coefficient $\gamma^{FG} + \gamma^{FVA}$, using variation in bilateral imports across partners within a given importer-industry-year cell.[28] Further, note that the DVA coefficient is now identified only by bilateral variation across partners within importer-industry-year cells. Lastly, exporter-industry-year fixed effects are included in all specifications.

In Panel A, column (1), we see that the OLS coefficients on the DVA ratio is negative:

[26] Most importers experience declines in their FVA ratios over time in the Textiles, Leather, and Footwear sector, because imports rise faster than FVA (which is also rising for most countries). Like the figure, our regression framework leverages *differences* in these changes across sectors and countries.

[27] When we include importer-industry-year fixed effects, using tariff preferences as the dependent variable is equivalent to using the applied tariff rate itself.

[28] Note that theory does not restrict the sign of this joint coefficient, so we do not seek to interpret its estimated sign or statistical significance. Although the joint coefficient need not be exactly equal to the sum of the γ^{FVA} and γ^{IP} from the specification with importer-industry and importer-year fixed effects, we find it is typically quite close.

Table 1: Bilateral Tariffs and Value-Added Content

Panel A: Baseline				
	OLS		Tobit	
	(1)	(2)	(3)	(4)
DVA ratio: $\ln(DVA^j_{xit}/IM^i_{xjt})$	-1.00***	-1.08***	-2.39***	-2.54***
	(0.27)	(0.30)	(0.51)	(0.53)
FVA ratio: $\ln(FVA^i_{xt}/IM^i_{xjt})$	-0.98***		-1.61***	
	(0.23)		(0.43)	
IP ratio: $\ln(FG^i_{xt}/IM^i_{xjt})$	2.17***		4.57***	
	(0.49)		(0.91)	
IP ratio + FVA ratio ($\gamma^{IP} + \gamma^{FVA}$)		1.27***		3.14***
		(0.32)		(0.59)
Observations	11,385	11,385	11,385	11,385
R-Squared	0.364	0.387		

Panel B: Controlling for RTAs				
	OLS		Tobit	
	(1)	(2)	(3)	(4)
DVA ratio: $\ln(DVA^j_{xit}/IM^i_{xjt})$	-0.43**	-0.47**	-1.03***	-1.09***
	(0.17)	(0.20)	(0.37)	(0.40)
FVA ratio: $\ln(FVA^i_{xt}/IM^i_{xjt})$	-0.71***		-1.17***	
	(0.19)		(0.34)	
IP ratio: $\ln(FG^i_{xt}/IM^i_{xjt})$	1.23***		2.45***	
	(0.34)		(0.66)	
IP ratio + FVA ratio ($\gamma^{IP} + \gamma^{FVA}$)		0.57***		1.36***
		(0.21)		(0.44)
Reciprocal Trade Agreement: RTA_{ijt}	-4.35***	-4.30***	-7.72***	-7.63***
	(0.60)	(0.61)	(1.06)	(1.05)
Observations	11,385	11,385	11,385	11,385
R-Squared	0.499	0.517		

Column Fixed Effects				
Importer-Year	Y	N	Y	N
Importer-Industry	Y	N	Y	N
Importer-Industry-Year	N	Y	N	Y
Exporter-Industry-Year	Y	Y	Y	Y

Note: Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

applied bilateral tariffs are lower (tariff preferences are larger) when the bilateral DVA ratio is high, consistent with the theoretical prediction. The coefficient is little changed in column (2), where we add an importer-industry-year fixed effect to hone in on variation across bilateral partners. To interpret the magnitudes, it is typical for the DVA ratio to vary by 5 log points across exporters within a given importer and industry, so moving from low to high DVA partners corresponds to roughly a 5 percentage point reduction in observed applied tariffs. Since the median tariff is around 8 percent in our data, this represents a substantial expansion of market access.

In column (1), applied bilateral tariffs are also lower when the multilateral FVA ratio is larger, consistent with political economy forces being relatively weak ($\delta_x^{FVA} < 1$). Focusing on time variation, some sectors see increases in the FVA ratio over time, with typical values on the order of 1 log point, while others see declines, with typical values of -1 log points. These differential changes lead to declines of about 2 percentage points in mean tariff preferences in sectors with growing FVA ratios relative to those with falling FVA ratios.

As a final point to note in column (1), the coefficient on the IP ratio is positive: a higher ratio of domestic final goods production to imports (or a lower import penetration ratio) is associated with higher tariffs, consistent with the government having stronger political economy incentives to protect domestic producers in this case. While this coefficient is of secondary interest to us as a control variable, we note the empirical importance of domestic political economy considerations is consistent with findings in Goldberg and Maggi (1999) and Gawande and Bandyopadhyay (2000).

Turning to Tobit estimates of the same specification in column (3), we see that adjusting for censoring pushes both the coefficients on the DVA ratio and FVA ratio away from zero, roughly doubling the size of the estimated coefficients. This is consistent with our interpretation that MFN tariffs represent a constraint on countries' use of bilateral discretion in tariff setting. Put differently, optimal tariffs appear to be about twice as sensitive to value-added content as actual applied tariffs.

In Panel B, we repeat the baseline estimation including an additional indicator variable RTA_{hjt} that takes the value one when countries h and j have a regional trade agreement (under WTO Article XXIV) in place at date t. The coefficient on RTA_{hjt} is the (conditional) mean difference in tariffs between pairs with and without an RTA in place. Though adding this control absorbs variation in bilateral tariffs, we continue to find negative and significant coefficients on both the DVA and FVA terms under both OLS in columns (1)-(2) and Tobit in columns (3)-(4).[29]

[29] Reflecting the fact that there is diminished residual variation after controlling for RTAs, the estimated coefficients are smaller (in absolute value) in Panel B than in Panel A. The RTA indicator substantially

Upstream and Downstream Differentiation With a baseline established, we now explore heterogeneity in the role of DVA across partners, where we can use bilateral variation for identification. Referring back to Equation (2.4), the response of the optimal tariff to DVA depends on the elasticity of pass-through from downstream price changes to the price of upstream GVC inputs (ε_{xh}^{rj}). All else equal, sectors in which final goods prices are more closely linked to the returns to GVC inputs should see a more pronounced (inverse) relationship between GVC income and tariffs. Further, the extent of product differentiation in upstream GVC inputs may be a proxy for input specificity, and thus the extent of pass-through from downstream output prices to upstream input prices.

To construct an empirical measure of upstream differentiation, we decompose domestic value-added in foreign production (DVA_{xh}^{j}) based on whether it originates in upstream industries that are plausibly differentiated or nondifferentiated.[30] We do this two ways.[31] First, we simply treat value added originating in the manufacturing sector as differentiated, and value added originating in the nonmanufacturing sector as non-differentiated. This is crude, but transparent. Second, we use the classification developed by Rauch (1999) to compute the share of value added from each upstream industry that is differentiated versus nondifferentiated. In both cases, adding up over upstream industries yields bilateral measures for DVA originating in differentiated upstream sectors ($DVA_{xh}^{j,Diff}$) versus undifferentiated sectors ($DVA_{xh}^{j,NonDiff}$). We then form DVA ratios with each of these components and repeat our baseline estimation.

We report results for this exercise in Panel A of Table 2, where all columns include importer-industry-year fixed effects. Columns (1)-(2) report coefficients for the manufacturing versus non-manufacturing split of upstream value added, whereas columns (3)-(4) report results using the Rauch classification. In all columns, we see that tariffs respond strongly to DVA originating from differentiated upstream industries, but are weakly related to DVA originating in non-differentiated industries, as expected.

negates the role for DVA in predicting which bilateral pairs form RTAs, and it also removes the average reduction in applied tariffs due to increasing RTA prevalence over time. Thus, by including the RTA indicator we discard important variation for pinning down both DVA and FVA effects.

[30]Pass-through elasticities may differ across country pairs because upstream sectors differ in the responsiveness of input prices to downstream output prices, and the *composition* of sectors that supply GVC inputs to downstream producers may differ across bilateral partners. For example, suppose that country h supplies a commodity (e.g., oil) and a differentiated manufactured input (e.g., electronic components) to downstream industry x in countries j and k. All else equal, we would expect returns to the commodity input to be relatively insensitive to changes in output prices for individual downstream producers that use it, while the returns to specialized inputs are likely to be sensitive to downstream product prices. Thus, if country h supplies predominantly commodity inputs to industry x in country j, but supplies predominantly differentiated inputs to industry x in country k, we would expect the pass-through from p_x^j to h's GVC income to be relatively low compared to the pass-through from p_x^k; i.e. $\varepsilon_{xh}^{rj} < \varepsilon_{xh}^{rk}$.

[31]See Appendix B.4 for details regarding implementation.

Turning our attention to downstream industries, note that the export supply elasticity dampens the impact of DVA on the optimal tariff in Equation (2.4). Since export supply elasticities (ϵ^j_{xh}) also tend to be correlated with measures of product differentiation [Broda, Limão and Weinstein (2008)], we then expect that tariffs in differentiated downstream sectors should be more responsive to DVA. We again consider two alternative classifications. We first allow for heterogeneous coefficients on the DVA ratio depending on whether the downstream industry is classfied as manufacturing versus nonmanufacturing. With the prior that manufacturing is differentiated while nonmanufacturing is not, we expect tariffs to respond more strongly to DVA in manufacturing. We then also classify downstream final goods sectors based on the Rauch classification, where we define a downstream industry to be differentiated if more than 50% of the underlying SITC categories in it are differentiated.

In Panel B of Table 2, we re-estimate the baseline model with importer-industry-year fixed effects, splitting coefficients across sectors based on whether they are differentiated or undifferentiated. In all cases, the coefficient on the DVA ratio is negative, suggesting that tariffs respond to value-added content in both sector groups. However, the coefficient for differentiated downstream industries tends to be larger (in absolute terms) in differentiated industries. This is most strongly true for the Rauch-based split, where we can reject equality of the coefficients at the 1% level.

2.4 Evidence for Temporary Trade Barriers

In addition to bilateral applied tariffs, governments use non-tariff barriers to restrict imports. In this section we examine whether GVC linkages influence a specific class of non-tariff barrier: temporary trade barriers (TTBs), which include antidumping, safeguard, and countervailing duties. In addition to being directly observable and politically salient trade policy instruments, temporary trade barriers are a natural testing ground for the theory. Countries have wide latitude under WTO rules to use TTBs, and they can be targeted at particular trading partners and products.[32] Prior research has found that non-tariff barriers generally, and TTBs specifically, appear to respond to optimal tariff considerations, which suggests TTBs may offer fertile territory for exploring the effects of DVA in particular.[33]

[32] For countries with low MFN tariffs, TTBs are one of the few WTO-consistent means by which to implement discriminatory trade policy, and accordingly, their use has been rising over time [Bown (2011)].

[33] Broda, Limão and Weinstein (2008) find that US NTBs are higher in sectors with high inverse export supply elasticities. Bown and Crowley (2013) find that United States' use of antidumping and safeguards is consistent with the Bagwell and Staiger (1990) model of self-enforcing trade agreements and cooperative tariffs. Trefler (1993) also used US NTB data in studying endogenous trade policy, and Goldberg and Maggi (1999) and Gawande and Bandyopadhyay (2000) used US NTB data in their empirical examination of the protection-for-sale model [Grossman and Helpman (1994)].

Table 2: Heterogeneity by Upstream and Downstream Differentiation

Panel A: Upstream Differentiation				
	Manuf. vs. Non-Manuf.		Rauch Classification	
	OLS	Tobit	OLS	Tobit
	(1)	(2)	(3)	(4)
DVA ratio (differentiated)	-1.21**	-2.34**	-2.40*	-4.78**
	(0.57)	(0.97)	(1.33)	(2.31)
DVA ratio (undifferentiated)	0.11	-0.20	1.38	2.45
	(0.43)	(0.92)	(1.20)	(2.28)
IP ratio + FVA ratio ($\gamma^{IP} + \gamma^{FVA}$)	1.26***	3.06***	1.20***	2.88***
	(0.31)	(0.57)	(0.28)	(0.52)
Observations	11,385	11,385	11,385	11,385
R-Squared	0.395		0.398	

Panel B: Downstream Differentiation				
	Manuf. vs. Non-Manuf.		Rauch Classification	
	OLS	Tobit	OLS	Tobit
	(5)	(6)	(7)	(8)
DVA ratio (differentiated)	-1.09***	-2.64***	-1.27***	-1.27***
	(0.29)	(0.54)	(0.32)	(0.29)
DVA ratio (undifferentiated)	-1.02***	-2.06***	-0.74**	-0.74***
	(0.38)	(0.58)	(0.29)	(0.26)
IP ratio + FVA ratio (differentiated)	1.28***	3.22***	1.50***	1.50***
	(0.31)	(0.59)	(0.34)	(0.31)
IP ratio + FVA ratio (undifferentiated)	1.25***	2.77***	0.90***	0.90***
	(0.42)	(0.64)	(0.31)	(0.28)
Observations	11,385	11,385	11,385	11,385
R-Squared	0.387		0.392	

Note: See Section 2.3.2 for definitions of differentiated and undifferentiated upstream and downstream sectors. All columns include importer-industry-year and exporter-industry-year fixed effects. Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

2.4.1 Data and Empirical Strategy

We obtain data from the World Bank's Temporary Trade Barriers Database [Bown (2016)]. These data identify the importing country imposing the TTB, the countries and product lines on which the TTB is imposed, and the timing of when TTBs are imposed and removed. Following Trefler (1993) and Goldberg and Maggi (1999), among others, we construct import coverage ratios, which measure the stock of accumulated TTBs. See Appendix B.3 for further data details.

In examining TTB use, our empirical specifications follow the approach for applied tariffs with two modifications. First, instead of measuring the downward deviation of applied bilateral tariffs from MFN tariffs, our dependent variable now measures the coverage ratio: the share country h's imports from trading partner j that face a positive TTB in a given year and sector. These coverage ratios follow the same sign conventions that we used for bilateral tariffs: lower coverage ratios are associated with lower trade protection. Second, we use lagged measures of value-added content in our regressions, since the TTB import coverage ratio (the dependent variable) measures the stock of TTBs in force, rather than the flow of new TTBs imposed/removed. Because TTBs typically remain in effect for a number of years, many TTBs in effect at date t were actually imposed in previous periods. Therefore, lagged value-added content better captures the information that was relevant to policymakers at the time when barriers currently in effect were actually adopted.

2.4.2 Results

Table 3 presents ordinary least squares estimates for TTB coverage ratios.[34] Columns (1) and (3) include results with importer-year, industry-year, importer-industry, and exporter-industry-year fixed effects, while columns (2) and (4) include importer-industry-year and exporter-industry-year fixed effects.[35] We find that both higher levels of domestic value added in foreign production and foreign value added in domestic production are associated with lower TTB coverage ratios. Governments appear to curb their protectionist TTB actions where value chain linkages are strongest.

[34] Although TTB coverage ratios have a mass point at zero, several arguments lead us to opt for OLS to analyze them, rather than limited dependent variable methods. First, positive values are relatively rare in the data, occurring in only 6 percent of our importer-exporter-industry-year cells. Binary outcome models are potentially biased in this context [King and Zeng (2001)]. Further, for Tobit models, the distribution of the rare positive outcomes is constrained to follow the extreme upper tail of the normal distribution, which seems untenable in our context. Second, as a practical matter, standard censoring arguments suggest that OLS coefficients of interest would be biased toward zero. Thus, OLS is a robust and likely conservative approach to characterizing our data.

[35] In the table, we cluster on importer-exporter-industry, because TTB policy decisions are independent across industries. The inferences we draw are robust to clustering by importer-exporter pair instead.

In our data, China is the exporter in approximately 30 percent of the importer-exporter-industry-year cells in which TTBs have been applied, roughly three times as many as the next highest exporter. Further, during our sample period, countries rarely impose TTBs in a given sector without also including China among the set of exporters on which barriers are imposed [Bown (2010), Prusa (2010)]. At face value, these observations suggest that most of the TTB use during this period is aimed at China. Recognizing this, we separately examine how bilateral value-added content influences TTB use depending on whether China is the exporting country, by interacting the DVA measure with an indicator for whether China is the exporter.[36] In Panel B of Table 3, we find that TTB coverage ratios are substantially more sensitive to DVA content when China is the exporter. There is some evidence for similar targeting for non-Chinese exporters in column (3), but it is substantially weaker. Thus we conclude that importers seem to target TTB use against China in a manner that shields their own upstream suppliers from harm.

3 Quantitative Exploration of Tariff Preferences

The empirical investigation above points to an important role for GVC linkages in shaping tariff preferences. In this section, we elaborate on the model in Section 2.1 to make it amenable to quantitative analysis. We then evaluate the impact of GVCs on tariffs via counterfactuals analysis.

3.1 Model Framework

On the consumer side, we assume there is a unit continuum of agents in each country; each agent has identical Gorman polar form preferences, so we describe preferences for the representative consumer. The consumer in country h has quasi-linear preferences over consumption of a homogeneous good and Armington-differentiated goods, which take the form:

$$U(d_0^h, \vec{d}^h) = d_0^h + \delta^h \left(d^h\right)^{\psi} \quad \text{with} \quad d^h = \left(\sum_{c=1}^{C} \left(d_c^h\right)^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)}, \tag{3.1}$$

where d_0^h is country h's consumption of the homogeneous good and d_c^h is the quantity of the differentiated good sourced by h from country c.[37] The parameter $\psi < 1$ governs the elasticity of demand for the composite d^h, $\delta_s^h > 0$ is a demand shifter, and $\sigma > 0$ is the

[36] Since both FVA and FG are multilateral (not bilateral), we have no expectation that they should impact TTB use against China differently from TTB use writ large.

[37] In the numerical analysis, we consider tariffs in a single sector, so we drop the sector notation here.

Table 3: Temporary Trade Barriers and Value Added Content

	(1)	(2)	(3)	(4)
DVA ratio	-0.22***	-0.19***		
	(0.061)	(0.066)		
DVA ratio (exporter = China)			-0.72***	-0.65***
			(0.25)	(0.24)
DVA ratio (exporter ≠ China)			-0.16***	-0.14**
			(0.054)	(0.061)
FVA ratio	-1.28***		-1.28***	
	(0.39)		(0.39)	
IP ratio	1.46***		1.43***	
	(0.40)		(0.40)	
IP ratio + FVA ratio		0.18***		0.14***
		(0.057)		(0.052)
Observations	10,098	10,098	10,098	10,098
R-Squared	0.235	0.477	0.239	0.480
Column Fixed Effects				
Importer-Year	Y	N	Y	N
Importer-Industry	Y	N	Y	N
Importer-Industry-Year	N	Y	N	Y
Exporter-Industry-Year	Y	Y	Y	Y

Note: Dependent variable in all columns is the temporary trade barrier coverage ratio for importer h against exporter j for final goods imports in industry x: TTB^h_{xjt}. The DVA ratio, FVA ratio, and IP ratios are lagged by 5 years to reflect information available when TTBs were adopted. In Panel B, the DVA ratio is interacted with an indicator for whether China is the exporting country. Standard errors (in parentheses) are clustered by importer-exporter-industry. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

elasticity of demand across sources for the differentiated good. The consumer's budget constraint is: $I^h = d^h_0 + \sum_c p^h_c d^h_c$, where I^h is income (defined below), p^h_c is the price of the good from country c for consumers in country h inclusive of tariff and non-tariff trade costs, and the price of the numeraire good is normalized to one.

Each agent $i \in (0, 1)$ is endowed with $l^h(i)$ units of homogeneous labor and $N^h(i)$ units of factor inputs that are used to produce differentiated goods, at home or abroad, which correspond to the GVC inputs discussed above. Aggregate factor endowments are then $L^h = \int_0^1 l^h(i)di$ and $N^h = \int_0^1 N^h(i)di$.

The productivity with which the GVC input supplied by agent i from country h may be used by producers in country c is $z^c_h(i)$. We assume this productivity is stochastic, as in the Roy-type models. Further, efficiency draws are independent across destinations and agents, taken from Fréchet probability distributions: $F_h^c(z) = \exp\left(-A_h^c z^{-\theta}\right)$, where $\theta > 1$ and $A_h^c \geq 0$. This Roy-Fréchet setup is an extension of Lagakos and Waugh (2013) and Galle, Rodríguez-Clare and Yi (2023); whereas they analyze the allocation of factors across sectors, we study factor allocation within global value chains.

Optimizing agents supply their GVC input to the country in which it yields the highest income. We assume that efficiency units supplied by a given country are perfectly substitutable in a given destination, so all agents from h earn the same return per effective unit supplied to c, which we denote $\bar{r}_h^c$. The probability that the agent has the highest payoff in destination c is:

$$\pi_h^c = \Pr\left(\bar{r}_h^c z_h^c \geq \max_{d \neq c}\left\{\bar{r}_h^d z_h^d\right\}\right). \tag{3.2}$$

The effective units of the input supplied by all agents to destination c is then:

$$\bar{\nu}_h^c \equiv N^h \pi_h^c \mathbf{E}\left[z_h^c | \bar{r}_h^c z_h^c \geq \max_{d \neq h}\left\{\bar{r}_h^d z_h^d\right\}\right]. \tag{3.3}$$

Total income accruing to each agent is the sum of labor income ($w^h l^h(i)$), GVC income given by $\frac{1}{N^h}\sum_c \bar{r}_h^c \bar{\nu}_h^c$, a lump sum rebate of tariff revenue ($R^h(i)$), and a per capita transfer from abroad ($B^h(i)$), which allows for trade imbalances in the data. Adding up across agents, income accruing to the representative consumer is: $I^h = w^h L^h + \sum_c \bar{r}_h^c \bar{\nu}_h^c + R^h + B^h$ where $R^h = \int_0^1 R^h(i)di = \sum_{c \neq h}\left(\frac{t_c^h}{1+t_c^h}\right) p_c^h d_c^h$ is tariff revenue, $B^h \equiv \int_0^1 B^h(i)di$, and transfers sum to zero across countries $\sum_c B^c = 0$.

Competitive producers in country h combine GVC inputs sourced from different countries with (local) homogenous labor to produce output, via the production function:

$$q^h = z^h \left(\sum_{c=1}^{C}\left(\nu_c^h\right)^{(\varrho-1)/\varrho}\right)^{\alpha\varrho/(\varrho-1)}\left(l^h\right)^{1-\alpha}, \tag{3.4}$$

where l^h is use of the homogeneous input, $\alpha \in (0,1)$ is the Cobb-Douglas share of the composite GVC input in production, and $\varrho \geq 0$ is the elasticity of substitution between the effective quantity of GVC inputs sourced from different countries (ν_c^h). Further, we assume there are iceberg frictions ($\kappa_c^h \geq 1$) that drive a wedge between buyer and seller prices, such that $r_c^h = \kappa_c^h \bar{r}_c^h$, where r_c^h is the buyer's price and $\bar{r}_c^h$ is the price received by the supplier. Market clearing for GVC inputs is given by: $\bar{\nu}_c^h = \kappa_c^h \nu_c^h$.

Turing to policy, the government's problem is the same as articulated in Section 2.1. Country h's government government chooses unilaterally optimal tariffs $\left\{t_c^h\right\}_{c \neq h}$ to maximize objective function $G^h = V^h + \delta^{DPE}\pi^h + \delta^{DVA}DVA^h + \delta^{FVA}FVA^h$, given tariffs set by other countries, the MFN constraint, and model equilibrium conditions. Because definitions of the elements in the objective function follow the prior model, we relegate them to the appendix.

3.1.1 Discussion

This setup has a number of desirable features for our analysis. First, though it is a rich quantitative model, it preserves the standard partial equilibrium structure of models used above, and the trade policy literature more generally. As a result, one can re-derive prior results using this model. Second, due to the parametric assumptions we have made, the model is amenable to calibration and simulation. For example, the model features standard gravity-type relationships for flows of consumer goods and value-added inputs.

In contrast to standard gravity models, however, the model features upward sloping supply curves for bilateral GVC inputs. This is a third desirable feature, which nests the specific factors models we considered previously. To explain, we show in the appendix that the supply of effective units of the GVC input by h to c can be written as:

$$\bar{\nu}_h^c = \Gamma\left(1 - \frac{1}{\theta}\right) A_h^c \left(\frac{\bar{r}_h^c}{\Phi^h}\right)^{\theta-1} N^h, \tag{3.5}$$

where $\Phi^h = \left(\sum_d A_h^d \left(\bar{r}_c^d\right)^{\theta}\right)^{1/\theta}$ is a CES-type supply price index and $\Gamma(\cdot)$ denotes the gamma function. Then, the partial elasticity of bilateral factor supply is $\frac{\partial \ln \bar{\nu}_h^c}{\partial \ln \bar{r}_h^c} = \theta - 1$. As θ rises, bilateral factor supply becomes more elastic, and vice versa. The case $\theta \to \infty$ corresponds to the case where GVC inputs are completely fungible across destinations, while $\theta \to 1$ corresponds to a model with specific GVC inputs at the bilateral level, as in Section 2.1.[38]

Lastly, note that equilibrium prices for GVC inputs are determined by equating supply and demand for them in the model.[39] As such, a host of parameters matter for pass-through of downstream output prices to GVC input prices. Both supply-side (θ) and demand-side (ϱ) substitution parameters matter, as well as auxiliary parameters (α) that govern the overall supply elasticity of downstream output. Further, the structure of trade linkages across countries also plays a role by mediating how demand-side (r^h) and supply-side (Φ^c) price

[38] In taking the limit $\theta \to 1$, one needs to normalize productivity so that $\Gamma\left(1 - \frac{1}{\theta}\right) A_h^c$ remains constant.

[39] Equating supply and demand for GVC inputs, and holding parameters fixed ($\hat{\kappa}_c^h = \hat{A}_c^h = \hat{N}^c = 1$), one can show that: $\ln \hat{\bar{r}}_c^h = \left(\frac{\varrho-1}{(\theta-1)+\varrho}\right) \ln \hat{r}^h + \left(\frac{\theta-1}{(\theta-1)+\varrho}\right) \ln \hat{\Phi}^c + \frac{1}{(\theta-1)+\varrho} \ln\left(\hat{\bar{p}}^h \hat{q}^h\right)$, where r^h is the price index for the CES composite GVC input and $\bar{p}^h$ is the price the producer receives for its output. For a given value of ϱ, suppose that we take $\theta \to 1$. Then, this expression collapses to collapses to: $\ln \hat{\bar{r}}_c^h = \left(\frac{\varrho-1}{\varrho}\right) \ln \hat{r}^h + \frac{1}{\varrho} \ln\left(\hat{\bar{p}}^h \hat{q}^h\right)$, which corresponds to a specific factors model, in which specific factors are paid their marginal product in production. As $\theta \to \infty$, then input supply becomes more elastic, and the prices for GVC inputs supplied to different destinations move in lock-step across destinations.

indexes depend on input prices. Given this complexity, we turn to quantitative evaluation of model mechanisms.

3.1.2 Solution and Calibration

We solve for optimal tariffs using a mathematical programming subject to equilibrium constraints (MPEC) routine, after rewriting the model to express the equilibrium and objective using exact hat algebra techniques. Details regarding the equilibrium conditions, solution procedure, and calibration are included in Appendix C, so we cover them briefly here.

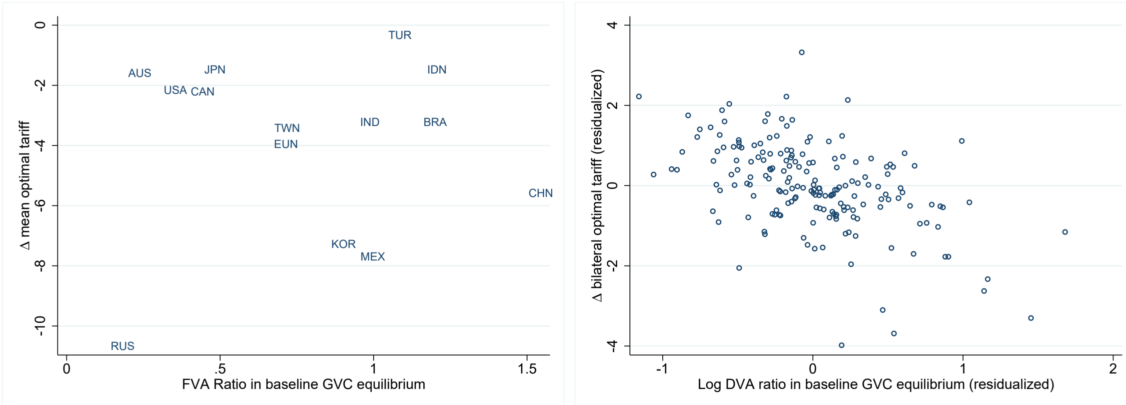
We use data on applied bilateral and MFN tariffs, trade flows for final goods and GVC inputs, aggregate GDP, and aggregate expenditure to set parameters needed to solve for optimal tariffs and simulate counterfactuals in the model. We aggregate data for a selected benchmark year (2005) to form a composite goods sector, for which measured tariffs are simple averages of applied bilateral and MFN tariffs across underlying sectors. We then externally calibrate several structural parameters. We set $\sigma = \varrho = 4$, based on standard values for trade elasticities from the literature. We assume $\alpha = 0.9$, so GVC inputs account for most of the value of output of the differentiated good. And we set $\psi = 0.5$, so the elasticity of demand for composite differentiated good is 2.

Parameters in the government's objective function are more difficult to calibrate a priori, so we proceed as follows. We set $\delta^{FVA} = 0$ based on introspection; recall that this is the weight the domestic government places on foreigners in its objective, which we think is plausibly small (consistent with the negative correlation between observed tariffs and FVA documented above). We then choose δ^{DPE} and δ^{DVA} by matching moments. The first two moments are regression coefficients, like those presented in Table 1; we regress applied tariffs for the composite goods sector on the log DVA ratio and log imports, with importer and exporter fixed effects. The third moment is the correlation between model-simulated tariff preferences and observed tariff preferences, conditional on observed preferences being non-zero, where the objective is to maximize this correlation. This procedure yields values $\delta^{DPE} = 1$ and $\delta^{DVA} = 9$. Thus, the political weight needed to match observed tariff preferences (given other parameters) is substantial.

3.2 Results

Applying the calibrated model, we now examine counterfactual experiments to gauge the responsiveness of optimal tariffs to GVC linkages. The first experiment examines how (constrained) optimal tariffs change as we raise the costs of trading GVC inputs. For illustration, we examine a scenario in which GVC input trade is completely eliminated, by taking

Figure 3: Increasing GVC Input Trade Costs to Impose GVC Autarky



(a) Change in Mean Tariff Preference with GVCs versus without GVCs

(b) Change in Bilateral Tariff Preference with GVCs versus without GVCs

Note: In each figure, we examine the difference between optimal tariffs (at the baseline equilibrium with GVC linkages) and counterfactual optimal tariffs with GVC autarky. On the x-axis, we plot measures of GVC linkages in the optimal tariff equilibrium with GVCs. In Sub-figure (b), we residualize the bilateral data by regressing it on importer and exporter fixed effects and log bilateral imports, using values from the optimal tariff equilibrium with GVCs.

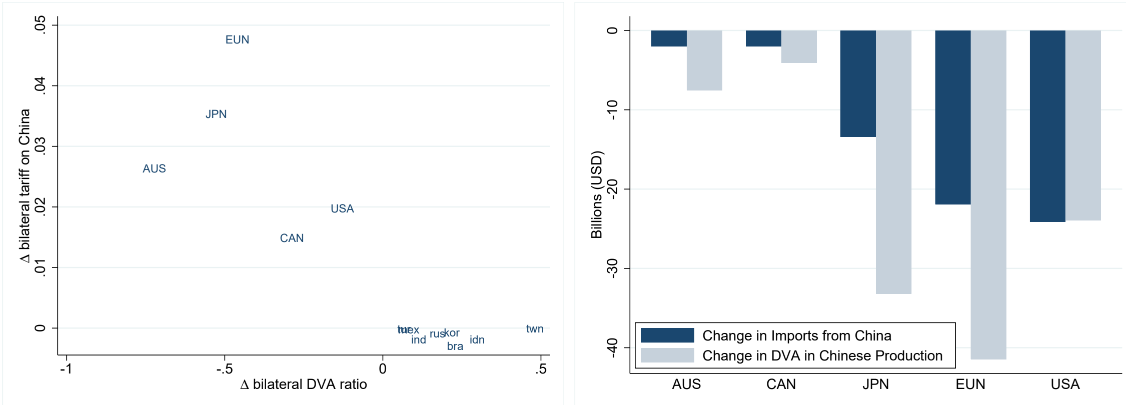
$\hat{\kappa}_c^d \to \infty$, which we refer to this as "GVC autarky." Naturally, GVC autarky raises optimal tariffs on average: the global mean optimal tariff is 5 percent in the baseline equilibrium, and it rises to 9.25 percent when GVC autarky is imposed. Correspondingly, the mean optimal preference is 4.9 percentage points in the baseline equilibrium, and it falls to 0.7 percentage points under GVC autarky. Thus, eliminating GVC linkages wipes out countries' desire to offer tariff preferences.

Under the surface, the effects of reduced GVC linkages are naturally heterogeneous across countries. We illustrate this in Figures 3a and 3b by plotting the difference between optimal tariffs with GVCs versus without them. In Figure 3a, we plot the difference in the mean tariff by importer versus the level of the FVA ratio for that country with GVCs.[40] Overall, there is a negative correlation, consistent with the theory. Further, the responsiveness of applied tariffs to GVC linkages is broadly consistent with those we recovered from the regression estimates in Section 2.3.2. At the same time, there is considerable heterogeneity, as endogenous responses of trade patterns, export supply elasticities, and pass-through elasticities to the GVC autarky experiment cut in different directions depending on the country.[41]

[40] Of course, in the GVC autarky equilibrium, the FVA ratio is zero. Thus, the x-axis could equivalently be thought of as representing the difference in the FVA ratio between the equilibrium with GVCs and the equilibrium without GVCs.

[41] Russia is an outlier in the figure. Whereas the model implies that Russia ought to grant substantial

Figure 4: Decoupling China from G7 Supply Chains



(a) Change in Bilateral Tariffs on China versus Change in Bilateral DVA Ratio

(b) Change in Imports from China and Domestic Value Added in Chinese Production

Note: This counterfactual restricts the supply of GVC inputs from G7 countries (Australia, Canada, the EU, Japan, and the US) to China. In Figure 4a, G7 countries are indicated by capital letters.

In Figure 3b, we present a related figure for bilateral tariffs and DVA. For visual presentation, we partial out the influence of multilateral determinants on optimal tariffs, as well as non-DVA political economy forces, by regressing simulated data on importer fixed effects, exporter fixed effects, and log imports as right-hand side variables (mimicking our prior empirical work). On the y-axis, we plot the residualized gap between bilateral tariffs in the equilibrium with GVCs and the equilibrium without them. We then plot the residualized log DVA ratio in the equilibrium with GVCs on the x-axis. As is evident, optimal tariffs with GVCs are lower relative to tariffs under GVC autarky for pairs that have high bilateral ratios of DVA to imports in the GVC trade equilibrium.

In a second experiment, we simulate a more targeted change in GVC links. Motivated by pervasive policy discussion about decoupling GVCs from China, for both national and economic security reasons, we examine the impact of removing China as a downstream partner in G7 value chains.[42] That is, for the G7 countries in our data, we restrict the supply of inputs to China, by taking A_c^{China} to zero for $c \in \{$Australia, Canada, EU, Japan,US$\}$.

The effects of this change on optimal tariffs are illustrated in Figure 4a. On the y-axis, we plot the change in each country's optimal final goods tariff applied to China. The x-axis

preferences to its trading partners, it does not do so in reality. This suggests that model-implied optimal tariffs for Russia may be unreliable, failing to capture its idiosyncratic features.

[42]Recall that the model is parameterized using data for 2005, so the tariff change here is the optimal tariff after decoupling from China less the optimal tariff in 2005, given the structure of trade and MFN constraints in 2005. We maintain this baseline for consistency across counterfactuals.

records the change in the bilateral DVA ratio for that country vis-á-vis China. The G7 countries have large declines in their DVA ratios, so they raise their optimal tariffs. Put differently, there is a degree of policy complementarity between measures to cut China off from G7 GVC inputs and tariffs on downstream imports from China.

Turning to Figure 4b, changes in DVA ratios for the G7 countries are a mixture of changes in DVA in Chinese goods (due to the policy itself) and the endogenous response of imports from China to those upstream policies. In particular, imports from China fall for all the G7 countries, because cutting off China's access to inputs raises China's production costs. This has heterogeneous effects among the G7 countries, depending on their initial trade exposure to China. For example, the US sees roughly equal decreases in its DVA in Chinese goods and imports from China. In contrast, the decline in DVA exceeds the decline in imports for China and Japan, which implies that they have larger declines in the DVA ratios and thus larger increases in their optimal tariffs.

As a final point, we note that tariffs are little changed by non-G7 countries, despite changes in their own DVA ratios against China. This lack of tariff response for the non-G7 countries speaks to non-linearities in the model, where these small countries have either lower pass-through elasticities and/or less market power against China than does the G7 block, leaving them with little incentive to use policy to manipulate their bilateral terms of trade.

In both counterfactual scenarios so far, we have entirely severed multilateral or bilateral GVC links. As such, these counterfactuals shed light on the total impact of GVCs on (constrained) optimal tariffs. As an intermediate case, recall that GVC integration has risen over time, from a lower level (though not autarky) at the beginning of our sample period (1995) to the end (2015). To assess this historical change in GVC linkages, we consider a third set of counterfactuals.

Using data on changes in final goods and GVC input trade, together with observed tariffs, we invert the model to recover changes in iceberg trade costs ($\{\hat{\kappa}_c^d, \hat{\tau}_c^d\}$ for $c \neq d$), GVC input supply ($\hat{N}^c$) and demand for differentiated goods $\hat{\delta}^c$ over time. With these inputs, we simulate the effects of changing GVC frictions ($\hat{\kappa}_c^d$) and input supply ($\hat{N}^c$) over time. To isolate these supply-side forces, we hold all other parameters fixed across years, including the MFN tariff bounds, which we set to their 1995 values. See Appendix C for further details on model inversion and simulation.

Focusing on first on aggregate tariffs, reductions in GVC frictions alone reduce the global mean optimal tariff by about 2 percentage points between 1995 and 2015. Adding changes in GVC input supply in addition to GVC frictions actually shrinks the global decline slightly, because the smaller supply of GVC inputs in 1995 lowers optimal tariffs relative to what they would have been if the supply of GVC inputs is held at its 2005 level. The decline in optimal tariffs due to changing GVC frictions is equal to just under half of the change implied by moving to GVC autarky, reported above. It is also equal to just under half of the observed decline in mean global tariffs over this period (about 4.5 percentage points). Again, these global results naturally obscure heterogeneity across trading partners, as the rise of GVC activity has been highly uneven. At the 25th percentile across countries pairs, tariffs fall by 11 percentage points, and these large declines are concentrated where increases in GVC activity are largest. Overall, we judge these results to be reasonable in magnitude relative to observed historical tariff changes.

4 Conclusion

This paper introduces a new value-added approach for exploring the role of global value chains in shaping trade policy. Fundamentally, GVCs erode the link between the location in which final goods are produced and the nationality of the value-added content embodied in those goods. Because import tariffs are by definition applied based on the location where goods are made, GVCs modify optimal tariff policy.

When domestic content in foreign final goods is high, governments' mercantilist incentive to manipulate the (final goods) terms-of-trade is eroded, leading to lower import tariffs all else equal. When foreign content in domestic final goods is high, some of the benefits of protection are passed back up the value chain to foreign suppliers, which also argues for lower tariffs. We find evidence in support of both of these predictions in two distinct empirical settings: when countries discriminate across trading partners using bilateral tariff preferences, and when countries discriminate through the imposition of temporary trade barriers. These results demonstrate the empirical importance of specific channels through which global value chains shape governments' trade policy choices. Further, through the analysis of quantitative counterfactuals, we show that these channels help us understand the structure of trade protection and changes in it over time.

We conclude with a few thoughts about future work in this area. First, we have focused on how governments set protection on final goods, setting aside empirical investigation of optimal input tariffs. We readily acknowledge a role for additional work on the determination of input tariffs themselves. As we discussed in Section 1.5, input tariffs are contingent on a host of issues that are largely irrelevant in the study of final goods tariffs, including the division of quasi-rents between downstream final goods producers and their input suppliers, possible hold-up problems, and complementarities across inputs in production. These issues present fertile territory for quantitative analysis, and very recent work by Beshkar and Lashkaripour (2020), Caliendo et al. (2023), and Antràs et al. (forthcoming) make early advances in this direction. The quantitative framework we have provided in this paper should prove useful in further applications in this vein.

Second, our analysis has focused on *bilateral* tariff preferences and TTB use. This setting distinguishes our work from the bulk of the trade policy literature, which focuses primarily on *multilateral* tariffs and non-tariff barriers. We have demonstrated that bilateral protection is a fertile testing ground for the theory of trade protection; future work is also likely to benefit from this empirically rich bilateral context to test alternative theories of trade policy formation. At the same time, we look forward to future work on the role of GVC linkages in shaping multilateral tariffs, with potential implications for the theory of trade agreements.

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Online Appendix: Global Value Chains and Trade Policy

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A Theory Appendix

A.1 Payments to Specific GVC Inputs

In the benchmark 2x2 model (Section 1.1) and the multi-country model (Section 2.1), we analyze tariffs with specific GVC inputs. This appendix provides details about how payments to these specific factors are determined for the 2x2 case; the multi-country case is a straightforward extension.

We assume there exists a representative GVC input supplier from each source country, where a supplier from country $d \in \{h, f\}$ owns v_d^c units of a specific factor that may be productively used only by downstream producers of good x in country c. Further, if any supplier withholds its GVC input, then production cannot take place and revenue is zero. The total surplus from production is $\pi_x^c(p^c; \vec{\nu}^c) \equiv p^c q_x^c(p^c; \vec{\nu}^c) - l_x^c(p^c; \vec{\nu}^c)$. Payments to GVC input suppliers are thus defined as: $\pi_d^c \in [0, \pi_x^c(p^c; \vec{\nu}^c)]$.[1]

We assume that these payments are determined via a cooperative game among GVC input suppliers, and we assume the production surplus is split according to a weighted Nash bargaining solution. Since factor owners correspond to the representative consumer in each country, maximizing their utility from the bargaining outcome amounts to maximizing the surplus they receive. Since the payoff space is convex and compact, the set of utilities associated with bargaining outcomes is also convex and compact. So, we write the bargaining problem directly in terms of maximizing the weighted product of the surplus payments:

$$\max_{\{\pi_d^c\}} \prod_{d \in \{h,f\}} (\pi_d^c)^{\alpha_d^c} \quad \text{s.t.} \quad \sum_{d \in \{h,f\}} \pi_d^c = \pi_x^c(p^c; \vec{\nu}^c), \tag{A1}$$

where $\{\alpha_d^c\}$ are the exogenous Nash bargaining weights and $\sum_d \alpha_d^c = 1$. The first order conditions characterizing the solution can be written as:

$$\pi_d^c = \alpha_d^c \pi_x^c(p^c; \vec{\nu}^c). \tag{A2}$$

Thus, each GVC input supplier receives a constant share of the total surplus. The return per unit of the GVC input supplied is a function of the downstream output price and parameters (including $\vec{\nu}^c$): $r_d^c(p^c; \vec{\nu}^c) \equiv \frac{\alpha_d^c \pi_x^c(p^c; \vec{\nu}^c)}{\nu_d^c}$.

[1] Because GVC inputs have no outside use, the outside option for all input suppliers is zero.

A.2 Proof of Proposition 1

To prove Proposition 1, we derive the necessary and sufficient conditions under which: (i) $\frac{d\tau^o}{d\nu_h^f} < 0$ and (ii) $\frac{d\tau^o}{d\nu_f^h} < 0$. These expressions are Conditions 1 and 2 in the text.

Recall that τ^o is given by the first order condition of Home's indirect utility function with respect to the tariff:

$$V_\tau(\tau^o) = 0, \tag{A3}$$

where $V_\tau \equiv \frac{dV^h}{d\tau} = \frac{\partial V(p^h,I^h)}{\partial p^h}\frac{dp^h}{d\tau} + \frac{\partial V(p^h,I^h)}{\partial I^h}\frac{dI^h}{d\tau}$, using $\frac{dI^h}{d\tau} = \frac{\partial I(p^h,p^f)}{\partial p^h}\frac{dp^h}{d\tau} + \frac{\partial I(p^h,p^f)}{\partial p^f}\frac{dp^f}{d\tau}$. Taking the total derivative of Equation (A3) characterizes the relationship between the optimal tariff and GVC inputs in DVA (ν_h^f) and FVA (ν_f^h):

$$V_{\tau\tau}d\tau^o + V_{\tau\nu_h^f}d\nu_h^f + V_{\tau\nu_f^h}d\nu_f^h = 0, \tag{A4}$$

where subscripts indicate derivatives, as in $V_{\tau\tau} \equiv \frac{d^2V^h}{d\tau^2}$, $V_{\tau\nu_h^f} \equiv \frac{d^2V^h}{d\tau d\nu_h^f}$, and $V_{\tau\nu_f^h} \equiv \frac{d^2V^h}{d\tau d\nu_f^h}$.

Consider part (i) of Proposition 1 first, focusing on ν_h^f while holding ν_f^h fixed. Evaluating Equation (A4) at the optimal tariff, we have:

$$\frac{d\tau^o}{d\nu_h^f} = -\frac{V_{\tau\nu_h^f}}{V_{\tau\tau}}\bigg|_{\tau^o}. \tag{A5}$$

By the second order condition of the optimal tariff problem, $V_{\tau\tau}\big|_{\tau^o} < 0$. Thus, the necessary and sufficient condition for the optimal tariff to be declining in ν_h^f reduces to:

$$\frac{d\tau^o}{d\nu_h^f} < 0 \iff V_{\tau\nu_h^f}\bigg|_{\tau^o} < 0. \tag{A6}$$

Using the first order condition in Equation (1.16), together with expressions (1.17) and (1.18), the market clearing condition, and the envelope condition at τ^o, we have:

$$\begin{aligned}
V_{\tau\nu_h^f}\bigg|_{\tau^o} &= \frac{d}{d\nu_h^f}\left(\frac{dV}{d\tau}\right) = \frac{d}{d\nu_h^f}\left(V_I\left\{(\tau^o-1)p^f\frac{dM_x}{d\tau} - M_x\frac{d\tilde{p}^f}{d\tau} - \frac{dr_f^h}{dp^h}\nu_f^h\frac{dp^h}{d\tau} + \frac{dr_h^f}{dp^f}\nu_h^f\frac{d\tilde{p}^f}{d\tau}\right\}\right) \\
&= \frac{d}{d\nu_h^f}\left(V_I\frac{d\tilde{p}^f}{d\tau}\underbrace{\left\{(\tau^o-1)E_x^f(\epsilon_x^f-1) - \frac{dr_f^h}{dp^h}\nu_f^h\frac{1}{\lambda} + \frac{dr_h^f}{dp^f}\nu_h^f\right\}}_{=0 \text{ at } \tau^o}\right) \\
&= V_I\frac{d\tilde{p}^f}{d\tau}\frac{d}{d\nu_h^f}\left((\tau^o-1)E_x^f(\epsilon_x^f-1) - \frac{dr_f^h}{dp^h}\nu_f^h\frac{1}{\lambda} + \frac{dr_h^f}{dp^f}\nu_h^f\right)\bigg|_{\tau=\tau^o}.
\end{aligned} \tag{A7}$$

Recognizing that $V_I > 0$ and $\frac{d\tilde{p}^f}{d\tau} < 0$, we can rewrite Equation (A6) as:

$$\frac{d\tau^o}{d\nu_h^f} < 0 \iff \frac{d}{d\nu_h^f}\left((\tau^o - 1)E_x^f(\epsilon_x^f - 1) - \frac{dr_f^h}{dp^h}\nu_f^h\frac{1}{\lambda} + \frac{dr_h^f}{dp^f}\nu_h^f\right)\Bigg|_{\tau^o} > 0 \tag{A8}$$

Rewriting the second inequality delivers Condition 1:[2]

$$\left[\frac{dr_h^f}{dp^f} + \frac{d}{d\nu_h^f}\left(\frac{dr_h^f}{dp^f}\right)\nu_h^f + \frac{d}{d\nu_h^f}\left(\frac{dr_f^h}{dp^h}\frac{1}{|\lambda|}\right)\nu_f^h + \frac{d}{d\nu_h^f}\left((\tau^o - 1)E_x^f(\epsilon_x^f - 1)\right)\right]\Bigg|_{\tau^o} > 0.$$

The indirect effects of a change in ν_h^f on Home's terms-of-trade motive and on pass-through rates (from tariffs to prices, embedded in λ, and from final goods prices to GVC income in the $\frac{dr_j^c}{dp^c}$ terms) are generally ambiguous in sign. As long as these indirect effects are not both negative and large, Condition 1 will be satisfied, and Home's optimal tariff will be decreasing in its domestic GVC inputs embodied in Foreign production.

The derivation of the necessary and sufficient condition for ν_f^h closely parallels that above, so we do not repeat it here; the result is Condition 2 in the text.

A.3 A Functional Form Example

This appendix presents a simple version of the model with quadratic utility and Cobb-Douglas production for the non-numéraire good. This exercise fixes ideas and allows us to derive the explicit form of the optimal tariff in terms of model primitives.

A.3.1 Set-up

The structure of the model follows Section 1.1, with additional assumptions that follow.

Functional Form Assumption 1. *Preferences are described by the following utility function:* $U(d_y^c, d_x^c) = \alpha d_y^c + \beta^c d_x^c - \frac{1}{2}{d_x^c}^2$ *for* $c \in \{h, f\}$*, where* $\alpha, \beta^c > 0$ *are exogenous parameters.*

Functional Form Assumption 2. *Technology is given by the production functions:* $q_x^c = (2\gamma l_x^c V^c)^{\frac{1}{2}}$ *and* $q_y^c = l_y^c$ *for* $c \in \{h, f\}$*, where* $\gamma > 0$ *is an exogenous technology parameter and* $V^c = \nu_h^c + \nu_f^c$ *represents the total composite value added used in production of good* x *in country* $c \in \{h, f\}$*.*

[2] The derivative $\frac{d(\cdot)}{d\nu_h^f}$ includes the direct influence of ν_h^f as well as any potential changes in final good prices. For economy of notation, we subsume these partial effects in the total derivative. For example, $\frac{d}{d\nu_h^f}\left(\frac{dr_h^f}{dp^f}\right) = \frac{\partial^2 r_h^f(p^f, \vec{\nu}^f)}{\partial p^f \partial \nu_h^f} + \frac{\partial^2 r_h^f(p^f, \vec{\nu}^f)}{\partial {p^f}^2}\frac{d\tilde{p}^f}{d\nu_h^f}$.

Functional Form Assumption 3. *Let* $r^c_h = r^c_f \equiv r^c$ *for* $c \in \{h, f\}$.

Functional Form Assumption 4. *Let* $\beta^h > \beta^f$ *and* $V^h = V^f \equiv V$.

The third assumption defines the division of quasi-rents between domestically-sourced and foreign-sourced GVC inputs, which can be interpreted as a restriction on the Nash bargaining weights. The fourth assumption ensures that x is Home's natural import good; equivalently, Foreign has comparative advantage in production of good x. Focusing on demand-side drivers of trade simplifies the derivation of the closed-form tariff expression. It also serves a valuable expositional role in our later comparative statics exercises, where we will hold the total level of composite value added input (V) fixed in each country while varying the *composition* of GVC inputs used in production across sources.

A.3.2 Solution

Production Profit maximization and labor market clearing together determine the supply functions for each good in each country $c \in \{h, f\}$:

$$q^c_x(p^c) = \gamma V p^c \quad \text{and} \quad q_y(p^c) = L^c - \frac{1}{2}\gamma V p^{c2}. \tag{A9}$$

The following zero profit condition pins down GVC income and the return to domestically-sourced GVC inputs in each country, as a function of the local price:

$$r^c(p^c)(\nu^c_h + \nu^c_f) = p^c q_x(p^c) - l^c_x(p^c) = \frac{1}{2}\gamma V p^{c2}. \tag{A10}$$

Thus, $r^c(p^c) = \frac{1}{2}\gamma p^{c2}, c \in \{h, f\}$ and $\varepsilon^{rc}_j \equiv \frac{dr^c_j}{dp^c}\frac{p^c}{r^c_j} = 2,\ c, j \in \{h, f\}$.

Consumption The (inverse) demand for each good is given by:

$$d^c_x(p^c) = \beta^c - \alpha p^c \quad \text{and} \quad d_y(p, I^c) = I^c - \beta^c p^c + \alpha p^{c2}, \tag{A11}$$

where income in Home and Foreign are given in Equation (1.10).

Market Clearing The international market clearing condition in Equation (1.13) pins down equilibrium prices. Substituting (A9) and (A11) into (1.13) and solving yields:

$$\tilde{p}^f(\tau) = \frac{\beta^h + \beta^f}{(\alpha + \gamma V)}\frac{1}{(\tau + 1)} \quad \text{and} \quad p^h(\tau) = \tau\tilde{p}^f(\tau) = \frac{(\beta^h + \beta^f)}{(\alpha + \gamma V)}\frac{\tau}{(\tau + 1)}. \tag{A12}$$

Notice $\tilde{p}^f(\tau)$ is decreasing in τ and $p^h(\tau)$ is increasing in τ.

The Optimal Tariff The expressions for supply, demand, and equilibrium prices described above deliver parsimonious expressions for the equilibrium trade volume, export supply elasticity, pass-through elasticities, and λ as a function of the tariff:[3]

$$E^f(\tau) = \frac{\beta^h - \beta^f \tau}{\tau + 1}, \quad \epsilon^f(\tau) = \frac{\beta^h + \beta^f}{\beta^h - \beta^f \tau}, \quad \lambda(\tau) = -1, \quad \text{and} \quad \varepsilon_h^{rf}(\tau) = \varepsilon_f^{rh}(\tau) = 2.$$

Substituting these expressions and the prices in (A12) into Equation (1.19) yields a closed-form solution for the optimal tariff:

$$\tau^o = \frac{2\beta^h + \beta^f - \gamma A \nu_h^f}{\beta^h + 2\beta^f + \gamma A \nu_f^h}, \tag{A13}$$

where $A \equiv \frac{(\beta^h + \beta^f)}{\alpha + \gamma V} > 0$.

Absent the influence of GVC linkages, the optimal tariff is strictly positive and follows the standard inverse-elasticity rule: $\tau^{tot} = \frac{2\beta^h + \beta^f}{\beta^h + 2\beta^f} > 1$. GVC linkages drive the optimal tariff below this benchmark. Taking the derivative of (A13) with respect to ν_h^f and ν_f^h yields the comparative statics analog to Proposition 1:[4]

Lemma 1. *Subject to Functional Form Assumptions 1-4, Home's optimal tariff is decreasing in the share of GVC-inputs used in production:*

$$\left.\frac{d\tau^o}{d\nu_f^h}\right|_{dV=0} < 0 \qquad \textit{and} \qquad \left.\frac{d\tau^o}{d\nu_h^f}\right|_{dV=0} < 0.$$

Proof. With $dV = 0$,

$$\frac{d\tau^o}{d\nu_f^h} = -\frac{\gamma A \nu_h^f \tau^o}{\beta^h + 2\beta^f + \gamma A \nu_f^h} < 0 \quad \text{and} \quad \frac{d\tau^o}{d\nu_h^f} = -\frac{\gamma A \nu_h^f}{\beta^h + 2\beta^f + \gamma A \nu_f^h} < 0.$$

A.4 The Optimal Tariff with Endogenous GVCs

This appendix generalizes the baseline 2x2 model to allow for endogenous changes in the use of value-added inputs across sectors and countries in response to price changes.

[3] ${E_x}^f(\tau) \equiv E_x^f(\tilde{p}^f(\tau)) = [q_x^f(\tilde{p}^f(\tau)) - d_x^f(\tilde{p}^f(\tau))]$. Likewise, let $\epsilon_x^f(\tau) \equiv \frac{dE_x^f}{dp^f}\frac{\tilde{p}^f(\tau)}{E_x^f(\tau)}$ and $\frac{dr^f}{dp^f}(\tau) \equiv \frac{dr^f}{dp^f}\big|_{\tilde{p}^f(\tau)}$; $\frac{dr^h}{dp^h}(\tau) \equiv \frac{dr^h}{dp^h}\big|_{p^h=\tau\tilde{p}^f(\tau)}$; and $\lambda(\tau) = \frac{dp^f/d\tau}{dp^h/d\tau}\big|_{p^f=\tilde{p}^f(\tau);p^h=\tau\tilde{p}^f(\tau)}$.

[4] From Assumption 4, $V = \nu_h^h + \nu_f^h = \nu_h^f + \nu_f^f$. Holding V fixed, therefore implies: $dV = 0 \rightarrow d\nu_h^f = -d\nu_f^f$ and $d\nu_f^h = -d\nu_h^h$. Under the functional forms adopted in this example, neither ν_h^h nor ν_f^f enter the optimal tariff expression (i.e. demand and supply for good x are independent of the composition of input sourcing), so the results in Lemma 1 are immediate.

As noted in the main text, we allow frictions to limit the substitutability of inputs across end-use sectors or destinations, so that the equilibrium returns to inputs may differ across countries. We do not provide explicit micro-foundations for these frictions here; we instead make direct assumptions about how the prices and quantities of GVC inputs behave. In Assumption A.1, we assume that *(i)* the return to, and the use of, the value-added inputs are weakly increasing in the local price of the final good that they are used to produce, and *(ii)* the vector of final goods prices uniquely pins down the global distribution and returns to value-added inputs. One particular set of supply-side assumptions that would yield this behavior are provided in the quantitative model in Section 3.

Assumption A.1. *Let:*

1. $r_j^c = r_j^c(p^c, \vec{\nu}^c(\vec{p})) \equiv r_j^c(\vec{p})$ *where* $\frac{\partial r_j^c(p^h,p^f)}{\partial p^c} \geq 0$ *for* $c, j \in \{h, f\}$,

2. $\nu_j^c = \nu_j^c(\vec{r}(\vec{p})) \equiv \nu_j^c(\vec{p})$ *where* $\frac{\partial \nu_j^c(p^h,p^f)}{\partial p^c} \geq 0$ *for* $c, j \in \{h, f\}$.

Here we adopt quasi-linear preferences, which removes potential income effects that otherwise complicate exposition: $U^c = d_0^c + u_x(d_x^c),\ c \in \{x, y\}$. As before, national income is given by:

$$I^h = q_y + p^h q_x^h(p^h, \vec{\nu}) + (p^h - p^f)M_x(p^h, \vec{\nu}) + \underbrace{r_h^f(\vec{p})\nu_h^f(\vec{p})}_{\equiv DVA_h(\vec{p})} - \underbrace{r_f^h(\vec{p})\nu_f^h(\vec{p})}_{\equiv FVA^h(\vec{p})}. \tag{A14}$$

The Home government chooses its optimal tariff to maximize aggregate indirect utility, subject to the arbitrage and market clearing conditions in Equations (1.12)-(1.13), which together pin down the equilibrium prices $\tilde{p}^f$ and $\tilde{p}^h = \tau\tilde{p}^f$ as a function of the tariff. The first order condition of the optimal tariff problem may be written as:

$$V_\tau = V_I\left[(\tau^o - 1)p^f \frac{dM_x}{d\tau} - M_x \frac{d\tilde{p}^f}{d\tau} + p^h \nabla_{\vec{\nu}}\, q_x^h \cdot D_\tau \vec{\nu} - \frac{dFVA^h}{d\tau} + \frac{dDVA_h}{d\tau}\right] = 0, \tag{A15}$$

where $\nabla_{\vec{\nu}} q_x^h$ denotes the (partial) gradient of $q_x^h(p^h, \vec{\nu})$ with respect to the GVC inputs in $\vec{\nu}$ and $D_\tau \vec{\nu}$ is the derivative of $\vec{\nu}$ with respect to the tariff.[5] Equation A15 generalizes Equation (1.16), by allowing the use of GVC inputs to depend on prices, and hence tariffs.

The first two terms in brackets reflect the terms-of-trade motive, while the third term captures any change in Home's production of the final good as a result of the endogenous change in the pattern of value-added input use. The last two terms capture the effect of a

[5] In terms of notation, we use ∇b to represent the (complete) (1×2) gradient of $b(\vec{p})$ with respect to the world price vector $\vec{p} = (p^h, p^f)$; $\nabla_{\vec{\nu}} a$ to represent the (partial) (1×4) gradient of $a(p, \vec{\nu})$ with respect to $\vec{\nu} \equiv (\nu_h^h, \nu_f^h, \nu_f^f, \nu_h^f)$; and $\frac{\partial \vec{\nu}}{\partial \vec{p}}$ for the (4×2) Jacobian of $\vec{\nu}(\vec{p})$. Thus, $\nabla_{\vec{\nu}}\, q_x^h \cdot D_\tau \vec{\nu} = \nabla_{\vec{\nu}}\, q_x^h \frac{\partial \vec{\nu}}{\partial \vec{p}} \cdot D_\tau \vec{p}$.

change in the tariff on GVC income. Applying the market clearing condition ($M_x = E_x^f$), we rewrite the first order condition:

$$\Big((\tau^o - 1)\epsilon_x^f - 1\Big)E_x^f \frac{d\tilde{p}^f}{d\tau} - p^f \nabla_{\vec{\nu}} E_x^f \cdot D_\tau \vec{\nu} + \nabla DVA_h \cdot D_\tau \vec{p} - \nabla FVA^h \cdot D_\tau \vec{p} = 0, \quad \text{(A16)}$$

where $\epsilon_x^f = \frac{\partial E_x^f(p^f,\vec{\nu})}{\partial p^f}\frac{p^f}{E_x^f}$ is the foreign export supply elasticity, ∇DVA_h and ∇FVA^h represent the gradients of each GVC income term with respect to the world price vector, and $D_\tau \vec{p} = (\frac{d\tilde{p}^h}{d\tau}, \frac{d\tilde{p}^f}{d\tau})$ is the derivative of the price vector with respect to the tariff.[6] Dividing through by the trade volume and $\frac{d\tilde{p}^f}{d\tau}$ yields:

$$(\tau^o - 1)\epsilon_x^f = 1 + \frac{\nabla FVA^h \cdot \vec{\Lambda}}{E_x^f} - \frac{\nabla DVA_h \cdot \vec{\Lambda}}{E_x^f} + \eta, \quad \text{(A17)}$$

where $\vec{\Lambda} \equiv \frac{D_\tau \vec{p}}{dp^f/d\tau} = \left(\frac{1}{\lambda}, 1\right)$ and we use $\eta \equiv \frac{p^f}{E_x^f}\nabla_{\vec{\nu}} E_x^f \frac{\partial \vec{\nu}}{\partial \vec{p}}\Lambda^\intercal$ to capture the change in final goods trade as a result of the endogenous change in input use.

Decomposing the GVC terms into pass-though elasticities and GVC income, we can write:

$$\frac{\nabla FVA^h \cdot \vec{\Lambda}}{E_x^f} = \frac{1}{E_x^f}\left(\nu_f^h \nabla r_f^h + r_f^h \nabla \nu_f^h\right) \cdot \vec{\Lambda} = \left(\frac{r_f^h \nu_f^h}{p^h E_x^f}\right)\Bigg(\underbrace{\frac{p^h}{r_f^h}\nabla r_f^h \cdot \vec{\Lambda}}_{\equiv -\tilde{\varepsilon}_f^{rh}} + \underbrace{\frac{p^h}{\nu_f^h}\nabla \nu_f^h \cdot \vec{\Lambda}}_{\equiv -\tilde{\varepsilon}_f^{\nu h}}\Bigg), \quad \text{(A18)}$$

$$\frac{\nabla DVA_h \cdot \vec{\Lambda}}{E_x^f} = \frac{1}{E_x^f}\left(\nu_h^f \nabla r_h^f + r_h^f \nabla \nu_h^f\right) \cdot \vec{\Lambda} = \left(\frac{r_h^f \nu_h^f}{p^f E_x^f}\right)\Bigg(\underbrace{\frac{p^f}{r_h^f}\nabla r_h^f \cdot \vec{\Lambda}}_{\equiv \tilde{\varepsilon}_h^{rf}} + \underbrace{\frac{p^f}{\nu_h^f}\nabla \nu_h^f \cdot \vec{\Lambda}}_{\equiv \tilde{\varepsilon}_h^{\nu f}}\Bigg). \quad \text{(A19)}$$

The terms $\tilde{\varepsilon}_f^{rh}$ and $\tilde{\varepsilon}_h^{rf}$ are analogs to the pass-through elasticity terms in the baseline specific factors model, capturing the change in the (per-unit) return to GVC inputs. The terms $\tilde{\varepsilon}_f^{\nu h}$ and $\tilde{\varepsilon}_h^{\nu f}$ are new: they reflect the change in the use of Foreign GVC inputs in home production, and Home GVC inputs used in foreign production.[7] Substituting using Equations (A18)-(A19) into Equation (A17) yields the implicit solution for Home's optimal tariff on final

[6] In this, we have decomposed the change in trade volume into the local-price effect versus "GVC relocation effect." Specifically, $\frac{dM_x}{d\tau} = \frac{dE_x^f}{d\tau} = \frac{\partial E_x^f(p^f,\vec{\nu})}{\partial p^f}\frac{d\tilde{p}^f}{d\tau} + \nabla_{\vec{\nu}}\ E_x^f \cdot D_\tau \vec{\nu}$, where $\nabla_{\vec{\nu}} E_x^f$ is the (partial) gradient of $E_x^f(p^f, \vec{\nu})$ with respect to the arguments in vector $\vec{\nu}$. Since there are no income effects, $\nabla_{\vec{\nu}} E_x^f \cdot D_\tau \vec{\nu} = -\nabla_{\vec{\nu}} q_x^h \cdot D_\tau \vec{\nu}$.

[7] We have defined these augmented pass-through elasticities to include the tariff-to-price mappings in $\vec{\Lambda}$, written to maintain the sign conventions in the main text. Thus, these elasticities capture the change in DVA and FVA as a result of a tariff change, allowing both the price and the quantity of GVC inputs to respond to the *complete* vector of world prices.

goods:

$$\tau^o = 1 + \frac{1}{\epsilon_x^f}\left(1 - (\tilde{\varepsilon}_h^{rf} + \tilde{\varepsilon}_h^{\nu f})\frac{DVA_h}{p^f E_x^f} - (\tilde{\varepsilon}_f^{rh} + \tilde{\varepsilon}_f^{\nu h})\frac{FVA^h}{p^h E_x^f} + \eta\right). \tag{A20}$$

As discussed in the main text, the pass-through elasticity terms that govern the relationship between GVC income and the optimal tariff depend on model primitives that determine structure of GVCs. These pass-through elasticities will be positive as long as GVC income is more sensitive to the price of final goods where the inputs are used, than to the price of final goods elsewhere in the world. In this 2x2 setting, this restriction takes the form:

$$\tilde{\varepsilon}_h^{\nu f} + \tilde{\varepsilon}_h^{\nu f} > 0 \iff \frac{\partial DVA(p^h, p^f)}{\partial p^f} > \frac{\partial DVA(p^h, p^f)}{\partial p^h}\frac{1}{|\lambda|} \tag{A21}$$

$$\tilde{\varepsilon}_f^{\nu h} + \tilde{\varepsilon}_f^{\nu h} > 0 \iff \frac{\partial FVA(p^h, p^f)}{\partial p^h}\frac{1}{|\lambda|} > \frac{\partial FVA(p^h, p^f)}{\partial p^f}. \tag{A22}$$

Sufficient international segmentation in input markets, whereby payments to GVC inputs depend most strongly on prices in the downstream location in which they are used, will ensure that these conditions obtain. This property holds in the quantitative model we develop in Section 3, but it may not hold in other models.[8] In the end, the empirical correlation of tariffs with value-added content is informative about whether these conditions hold.

Depending on the assumptions about the underlying market structure governing input use, some of all of the η term may cancel with the endogenous input reallocation components of the DVA and FVA terms. For instance, if inputs are paid their value marginal product at Home, and as the absence of barriers to input trade drives the return to Home's value-added inputs to converge across countries, then η will cancel with the $\tilde{\varepsilon}^\nu$ terms. Formally:

Lemma 2. *If $r_f^h = p^h \frac{\partial q_x^h}{\partial \nu_f^h}$ and $r_h^h = p^h \frac{\partial q_x^h}{\partial \nu_h^h}$, then as $r_h^h \to r_h^f$ and if $d\nu_h^f \to -d\nu_h^h$, then:*

$$\tau^o \to 1 + \frac{1}{\hat{\epsilon}_x^f}\left(1 - \tilde{\varepsilon}_h^{rf}\frac{DVA_h}{p^f E_x^f} - \tilde{\varepsilon}_f^{rh}\frac{FVA^h}{p^h E_x^f}\right),$$

where $\hat{\epsilon}_x^f \equiv \left[\frac{\partial E_x^f(p^f,\vec{\nu})}{\partial p^f} + \nabla_{\vec{\nu}}\, E_x^f \cdot \left(D_{p^f}\vec{\nu} + D_{p^h}\vec{\nu}\frac{1}{\lambda}\right)\right]\frac{p^f}{E_x^f}$ is the elasticity of export supply allowing for endogenous changes in value-added input use across countries.

Proof. Substituting the conditions $r_f^h = p^h \frac{\partial q_x^h}{\partial \nu_f^h}$ and $r_h^f = r_h^h = p^h \frac{\partial q_x^h}{\partial \nu_h^h}$ and $d\nu_h^f = -d\nu_h^h$ into the first order condition in (A15), cancelling terms, and solving yields the result.

[8]For example, Ludema et al. (2021) finds that when inputs are highly substitutable across end-uses and countries and inelastically demanded by downstream producers, it is possible that an increase in a home country's tariff could cause DVA to fall. For this to occur, the increase in the home tariff would need to drive up local demand for the (tradeable) GVC input in Home enough to outweigh the price impact of the concomitantly lower demand for the GVC input overseas.

A.5 Endogenous Input Tariffs with Endogenous GVCs

We now introduce input tariffs to the general equilibrium model with endogenous GVCs. The model and assumptions are as described in Appendix A.4, with one change. We now permit the home country to levy an ad-valorem tax on foreign-sourced inputs used in domestic production: $g \in [0,1]$, applied to the local price of imported inputs, r_f^h, so that trade tax revenue is now:

$$R^h = (p^h - p^f)M_x^h + gFVA_s^h. \tag{A23}$$

National income is given by:

$$I^h = q_y + p^h q_x^h(p^h, \vec{\nu}) + (p^h - p^f)M_x(p^h, \vec{\nu}) + \underbrace{r_h^f(\vec{p})\nu_h^f(\vec{p})}_{\equiv DVA_h(\vec{p})} - (1-g)\underbrace{r_f^h(\vec{p})\nu_f^h(\vec{p})}_{\equiv FVA^h(\vec{p})}. \tag{A24}$$

The Home government (again) chooses its optimal tariffs to maximize aggregate indirect utility, subject to the arbitrage and market clearing conditions in Equations (1.12)-(1.13).

The Optimal Tariff on Final Goods Given any arbitrary input tariff g, the optimal tariff on final goods is described implicitly by the first order condition:

$$V_\tau = V_I\left[(\tau^o - 1)p^f \frac{dM_x}{d\tau} - M_x \frac{d\tilde{p}^f}{d\tau} + p^h \nabla_{\vec{\nu}}\, q_x^h \cdot D_\tau \vec{\nu} - (1-g)\frac{dFVA^h}{d\tau} + \frac{dDVA_h}{d\tau}\right] = 0. \tag{A25}$$

The only difference between this expression and that in (A15) is the introduction of the coefficient $(1-g)$ on the FVA term. Consistent with the discussion in Section 1.5, this new term reflects the fact that an input tariff allows the Home government to recapture some of the protectionist rents associated with its final goods tariff that would otherwise flow to foreign-owned GVC inputs. Following the same solution methodology in Appendix A.4, it is straightforward to show the the optimal final goods tariff in the presence of an arbitrary input tax on foreign-sourced value-added inputs is given by:

$$\tau^o = 1 + \frac{1}{\epsilon_x^f}\left(1 - (\tilde{\varepsilon}_h^{rf} + \tilde{\varepsilon}_h^{\nu f})\frac{DVA_h}{p^f E_x^f} - (1-g)(\tilde{\varepsilon}_f^{rh} + \tilde{\varepsilon}_f^{\nu h})\frac{FVA^h}{p^h E_x^f} + \eta\right). \tag{A26}$$

The Optimal Input Tariff The optimal input tariff is defined implicitly by the following first order condition:

$$V_g = V_I\left[(\tau - 1)p^f \frac{dM_x}{dg} - M_x \frac{d\tilde{p}^f}{dg} + p^h \nabla_{\vec{\nu}} q_x^h \cdot D_g \vec{\nu} + \frac{dDVA_h}{dg} - (1-g^o)\frac{dFVA^h}{dg} + FVA\right] = 0. \tag{A27}$$

Applying the market clearing condition and reorganizing terms, we then have:

$$(g^o - 1) \underbrace{\left[r_f^h \frac{d\nu_f^h}{dg} + \nu_f^h \frac{dr_f^h}{dg} \right]}_{\equiv \frac{dFVA^h}{dg}} - r_f^h \nu_f^h - p^h \nabla_{\vec{\nu}} q_x^h \cdot D_g \vec{\nu} = (\tau - 1) p^f \frac{E_x^f}{dg} - E_x^f \frac{d\tilde{p}^f}{dg} + \underbrace{\nabla DVA_h \cdot D_g \vec{p}}_{\equiv \frac{dDVA_h}{dg}},$$

If value-added inputs used in Home production are paid their value marginal product, so that $r_j^h = p^h \frac{\partial q_x^h(p^h, \vec{\nu})}{\partial \nu_j^h}$, $j \in \{h, f\}$, we can further simplify this first order condition to:

$$\left(g^o \xi_f^h - 1 \right) \frac{dr_f^{h*}}{dg} \nu_f^h = (\tau - 1) p^f \frac{E_x^f}{dg} - E_x^f \frac{d\tilde{p}^f}{dg} + \nabla DVA_h \cdot D_g \vec{p} + r_h^h \frac{d\nu_h^h}{dg}, \tag{A28}$$

where $r_f^{h*} \equiv (1 - g) r_f^h$ and $\xi_f^h \equiv \frac{r_f^h}{\nu_f^h} \nabla_{\vec{r}} \nu_f^h \cdot D_g \vec{r} \frac{1}{dr_f^h / dg}$ is the elasticity of foreign GVC inputs used in Home production with respect to the change in the rates of return paid to Foreign GVC inputs.

From here, we make two observations. First, the optimal input tariff (like the optimal final goods tariff) follows an own inverse elasticity rule, moderated by GVC cross-linkages (how final goods trade, and therefore tariff revenue associated with final goods trade, changes with g; how DVA responds to g, and how the return to home's domestically-used value-added inputs (ν_h^h) changes with g). Second, the behavior and sign of these cross-effects will depend on model primitives, including whether home and foreign value-added inputs are complements or substitutes in production of final goods and whether the induced reallocation of GVC inputs makes global production of final goods more or less efficient (so that $\frac{dp^f}{dg} \lesseqgtr 0$).

As a final point, note that if both the optimal tariff on final goods and the optimal input tariff are characterized by interior solutions, they are described by Equations (A25) and (A27). In the resulting optimal tariff solution, some (but not all) of the cross-effects in (A28) may be eliminated by applying envelope conditions *if there are no other frictions to input trade and input markets are perfectly competitive.* Even so, general results are elusive, as Antràs and Chor (2022) make clear. Note that considerable caution must be exercised in this environment, since many standard modelling assumptions about the nature of GVCs (including specific factors) lead to corner solutions where the first order condition for input tariffs will not obtain.

A.6 Many-Country, Many-Good, Political Economy Model

This appendix provides details about the many-country, many-good model with political economy presented in Section 2.1.

A.6.1 Set-up

Consider a many-country world, where the set of countries is $\mathcal{C} = \{0, 1, ..., C\}$. There are $S+1$ final goods, and let the numéraire good be indexed by 0, while all other (non-numéraire) final goods are in the set $\mathcal{S} = \{1, ..., S\}$. The price of final good $s \in \mathcal{S}$ in country $c \in \mathcal{C}$ is p_s^c. The numéraire good is freely traded, so that $p_0^c = 1 \; \forall \; c \in \mathcal{C}$. We use $\vec{p}^c = (p_1^c, ..., p_S^c)$ to denote the $(1 \times S)$ vector of (non-numéraire) final goods prices in country c, $\vec{p}_s = (p_s^0, ..., p_s^C)$ to denote the $(1 \times C+1)$ vector of sector s prices in each country, and $\vec{p} = (\vec{p}^0, ..., \vec{p}^C)$ to represent the complete $(1 \times S(C+1))$ vector of non-numéraire final goods prices.[9]

Preferences Each country is populated by a continuum of identical agents with quasi-linear preferences, represented by the aggregate utility function:

$$U^c(d_0^c, \vec{d_s}^c) = d_0^c + \sum_{s \geq 1} u_s(d_s^c), \tag{A29}$$

where d_s^c is the aggregate consumption of final good s in country c and sub-utility over each non-numéraire good, $u_s(\cdot)$, is increasing, continuously differentiable, and strictly concave. We assume that every individual has sufficient income to consume a strictly positive quantity of the numéraire, so that preferences over non-numéraire goods satisfy Gorman form.

Endowments Every country $c \in \mathcal{C}$ is endowed with a homogeneous factor, L^c,

Technology Atomistic firms produce final goods in perfectly competitive markets. Technology is summarized by the constant returns to scale production functions:

$$q_s^c = f_s^c(l_s^c, \nu_{sc}^c, \vec{\nu}_{s*}^c) \qquad \text{and} \qquad q_0^c = l_o^c, \tag{A30}$$

where q_s^c is the quantity of final good s produced by country c using l_s^c units of (homogeneous) labor, ν_{sc}^c units of the domestic GVC input, and a $(1 \times C)$ vector of GVC inputs sourced from countries $j \neq c \in \mathcal{C}$, given by $\vec{\nu}_{s*}^c$. As in the benchmark model in Section 1.1, we assume that the GVC inputs are specific factors, with inelastic supply.

Tariffs and Timing. As before, we focus attention on import tariffs and rule out export taxes. A given Home government may impose discriminatory bilateral ad-valorem tariffs

[9] It later proves useful to partition price vectors into domestic and foreign components. From the perspective of a given country $h \in \mathcal{C}$, $\vec{p} \equiv (\vec{p}^h, \vec{p}^*)$, where $\vec{p}^*$ is the $(1 \times SC)$ vector of prices in every country $j \neq h \in \mathcal{C}$. Likewise, let $\vec{p}_s \equiv (p_s^h, \vec{p}_s^*)$ where $\vec{p}_s^*$ is the $(1 \times C)$ vector of prices for good s in every country other than country h.

on its imports from each of its potential trading partners, applied to the foreign selling price. Following the literature, we introduce political economy influences by assuming that the Home government maximizes the sum of aggregate indirect utility and a set of "special interest factors" associated with the quasi-rents from production in different sectors. The objective is provided by Equation 2.2.

The government chooses the vector of its tariffs on every imported good against every trading partner to maximize its objective function subject to balanced budget and market clearing conditions, and taking any other countries' policies as given. Firms then maximize profits and consumers maximize welfare, taking tariffs as given. We rule out the possibility of the Metzler and Lerner paradoxes by assumption. Specifically, using τ_{sc} to denote (one-plus) the 'home' ad-valorem tariff on good s imported from country $c \neq h \in \mathcal{C}$ and $\tilde{p}_s^c$ ($\tilde{p}_s^h$) for the equilibrium price of good s in country c (h), then for any non-prohibitive tariff, we assume that: $\frac{d\tilde{p}_s^c}{d\tau_{sc}} \leq 0 \leq \frac{d\tilde{p}_s^h}{d\tau_{sc}}$.

A.6.2 Solution

Production In every country $c \in \mathcal{C}$, profit maximization by atomistic firms and local labor market clearing determine the supply function for each final good $s \in \mathcal{S}$ as a function of local final goods prices, taking value-added inputs and total labor endowment as given:

$$q_s^c(p_s^c; \vec{\nu}_s^c) = f_s^c(l_s^c(p_s^c), \nu_{sc}^c, \vec{\nu}_{s*}^c) \; \forall s \tag{A31}$$

$$q_0^c(\vec{p}^c; \vec{\nu}^c) = L^c - \sum_s l_s^c(p_s^c; \vec{\nu}_s^c), \tag{A32}$$

where $l_s^c(p_s^c; \vec{\nu}_s^c) = \arg\max_{l_s^c} \; p_s^c f_s^c(l_s^c, \nu_{sc}^c, \vec{\nu}_{s*}^c) - l_s^c \; \forall s \in \mathcal{S}$.

As in the benchmark model, we assume that any production surplus is split according to a Nash bargaining protocol among owners of the specific GVC inputs. The argument follows the same structure as Appendix A.1, so we do not repeat it here. Returns to the GVC inputs may be represented by the function $r_{sj}^c(p_s^c; \vec{\nu}_s^c)$, which satisfies $\frac{\partial r_{sj}^c(p_s^c; \vec{\nu}_s^c)}{\partial p_s^c} > 0$. Denoting the total production surplus by $\pi_s^c(p_s^c)$, then the following holds:

$$\pi_s^c(p_s^c) = p_s^c q_s^c(p_s^c) - l_s^c(p_s^c) = \sum_{j \in \mathcal{C}} r_{sj}^c(p_s^c; \vec{\nu}_s^c)\nu_{sj}^c. \tag{A33}$$

Consumption With quasi-linear preferences, aggregate demand for non-numéraire goods is independent of income. In every country $c \in \mathcal{C}$:

$$\begin{aligned} d_s^c(p_s^c, I^c) &\equiv d_s^c(p_s^c) = u_s'^{-1}(p_s^c) \qquad \forall s \in \mathcal{S} && \text{(A34)} \\ d_0^c(\vec{p}^c, I^c) &= I^c - \sum_s p_s^c d_s^c && \text{(A35)} \\ V(\vec{p}^c, I^c) &= \zeta^c(\vec{p}^c) + I^c, && \text{(A36)} \end{aligned}$$

where $V(\vec{p}^c, I^c)$ is aggregate indirect utility and $\zeta^c \equiv \sum_s [u_s(d_s^c) - p_s^c d_s^c]$ is total consumer surplus in country c. For each country $c \in \mathcal{C}$, national income (measured in the numéraire) is given by:

$$I^c = q_0^c + \vec{p}^c \cdot \vec{q}^c(\vec{p}^c, \vec{\nu}^c) + R^c + \sum_s \underbrace{\sum_{j \neq c} r_{sc}^j(p_s^j; \vec{\nu}_s^j)\nu_{sc}^j}_{\equiv DVA_{sc}} - \sum_s \underbrace{\sum_{j \neq c} r_{sj}^c(p_s^c; \vec{\nu}_s^c)\nu_{sj}^c}_{\equiv FVA_s^c}, \tag{A37}$$

where tariff revenue is $R^c = \sum_s \sum_{j \neq c}(p_s^c - p_s^j) M_{sj}^c(\vec{p}_s; \vec{\nu}_s)$ and $M_{sj}^c(\cdot)$ is country c's imports of good s from country j.

Market Clearing Prices are disciplined by a set of SC no-arbitrage conditions: $p_s^h \leq \tau_{sc}^h p_s^c$, $\forall c \neq h \in \mathcal{C}, s \in \mathcal{S}$.[10] Equilibrium prices are then determined by the set of S market clearing conditions that ensure demand equals supply globally for each non-numéraire good:

$$\sum_{c \in \mathcal{C}} d_s^c(\tilde{p}_s^c) = \sum_{c \in \mathcal{C}} q_s^c(\tilde{p}_s^c; \vec{\nu}_s^c) \qquad \forall\, s \in \mathcal{S}. \tag{A38}$$

Balanced budget conditions for each country clear the market for the numéraire.

A.6.3 Politically-Motivated Bilateral Tariffs

Home's politically optimal tariff schedule, $\vec{\tau}^o$, maximizes its government objective function (Equation 2.2) subject to market clearing conditions (Equation (A38)):

$$\begin{aligned} \vec{\tau}^o = \arg\max_{\vec{\tau}} \; & V^h + \sum_s [\delta_s^{PE} \pi_s^h + \delta_s^{DVA} DVA_{sh} + \delta_s^{FVA} FVA_s^h] && \text{(A39)} \\ \text{s.t.} \quad & p_s^h \leq \tau_{sc}^h p_s^c \text{ and } p_s^c = \tilde{p}_s^c \; \forall\, c \neq h \in \mathcal{C}, s \in \mathcal{S} \end{aligned}$$

Home has SC first order conditions, one for every (non-numéraire) sector $s \in \mathcal{S}$ and trading partner $c \neq h \in \mathcal{C}$. Notice that with quasi-linear preferences and a numériare good, there

[10] These bilateral arbitrage relationships hold with equality in the presence of trade: $M_{sc}^h > 0 \Rightarrow p_s^h = \tau_{sc}^h p_s^c$.

are no cross-price effects across sectors. The following first order condition implicitly defines the optimal bilateral, sector-specific tariff (τ^h_{xj}):

$$G^h_{\tau^h_{xj}} = (\tau^h_{xj} - 1)p^j_x \frac{dM^h_{xj}}{d\tau^h_{xj}} - M^h_{xj}\frac{dp^j_x}{d\tau^h_{xj}} + \delta^{PE}_x q^h_x \frac{dp^h_x}{d\tau^h_{xj}} + \Omega^R_{xj} + (1+\delta^{DVA}_x)\frac{dDVA_{xh}}{d\tau^h_{xj}} - (1-\delta^{FVA}_x)\frac{dFVA^h_x}{d\tau^h_{xj}} = 0. \quad \text{(A40)}$$

The term Ω^R_{xj} captures the potential for trade diversion to change Home's tariff revenue from trade with countries other than j.[11] Apart from this trade diversion term, and the political economy weights attached to the DVA and FVA terms, the last substantive modification is the introduction of domestic political economy concerns, weighted by δ^{PE}_s.

We now decompose the two GVC terms into pass-through elasticities and directly-observable measures of GVC income. Consider first the role of foreign value added embodied in domestic final goods (FVA). The bilateral tariff raises the local final goods price at Home (p^h_x), which in turn increases the returns to foreign GVC inputs embodied in Home's domestic production via $r^h_{xc}(p^h_x; \vec{\nu}^h_x)$. We decompose this effect as follows:

$$\frac{dFVA^h_x}{d\tau^h_{xj}} = \sum_{c\neq h}\left[\frac{r^h_{xc}\nu^h_{xc}}{p^h_x}\underbrace{\left(\frac{dr^h_{xc}}{dp^h_x}\frac{p^h_x}{r^h_{xc}}\right)}_{\equiv\varepsilon^{rh}_{xc}\geq 0}\right]\frac{dp^h_x}{d\tau^h_{xj}} = \varepsilon^{rh}_{x*}\sum_{c\neq h}\frac{r^h_{xc}\nu^h_{xc}}{p^h_x}\frac{dp^h_x}{d\tau^h_{sj}} = \varepsilon^{rh}_{x*}\frac{FVA^h_x}{p^h_x}\frac{dp^h_x}{d\tau^h_{xj}} \quad \text{(A41)}$$

The term $\varepsilon^{rh}_{xc} \equiv \frac{dr^h_{xc}}{dp^h_x}\frac{p^h_x}{r^h_{xc}}$ is the elasticity of foreign GVC input prices with respect to local final goods prices at Home. This elasticity is positive: a higher price on a final good implies higher returns to the specific GVC inputs used in its production. In preparation for the empirical application, we further assume that this elasticity is the same across all foreign input sources, so that $\varepsilon^{rh}_{xc} = \varepsilon^{rh}_{x*}\ \forall\ c \neq h \in \mathcal{C}$, as reflected the second equality above.

Turning to the role of domestic value added in foreign final goods (DVA), the bilateral tariff alters foreign final goods prices, which feed back into the price of domestic GVC inputs. We decompose the direct and indirect price effects of the tariff as follows:

$$\frac{dDVA_{xh}}{d\tau^h_{xj}} = \frac{r^j_{xh}\nu^j_{xh}}{p^j_x}\underbrace{\left(\frac{dr^j_{xh}}{dp^j_x}\frac{p^j_x}{r^j_{xh}}\right)}_{\equiv\varepsilon^{rj}_{xh}\geq 0}\frac{dp^j_x}{d\tau^h_{xj}} + \underbrace{\sum_{c\neq h,j}\frac{dDVA^c_{xh}}{dp^c_x}\frac{dp^c_x}{d\tau^h_{xj}}}_{\equiv\Omega^{DVA}_{xj}} = \underbrace{\varepsilon^{rj}_{xh}\frac{DVA^j_{xh}}{p^j_x}\frac{dp^j_x}{d\tau^h_{xj}}}_{\text{direct effect}} + \Omega^{DVA}_{xj} \quad \text{(A42)}$$

[11]For any $s \in \mathcal{S}$, $\Omega^R_{sj} \equiv \sum_{c\neq j,h}(\tau_{sc}-1)\left[\frac{d\tilde{p}^c_s}{d\tau_{sj}}M_{sc} + p^c_s\frac{dM_{sc}}{d\tau_{sj}}\right]$. These trade diversion effects, which are typical in multi-country trade models, are generally ambiguous. They are plausibly negligible when trade diversion is minimal, as would be consistent with evidence surveyed by Freund and Ornelas (2010).

The direct effect captures the impact of an increase in τ^h_{xj} on the return to Home's GVC inputs used by the country (j) on which the tariff is imposed. We collect any potential indirect effects – how the Home's tariff on country j might impact the return of Home's GVC inputs used in third countries – in Ω^{DVA}_{xj}.[12] The strength of this direct effect is governed by the elasticity ε^{rj}_{xh}, which is again positive: a higher price of good x in country j implies a higher price for Home's GVC inputs used in production of that good.

Substituting Equations (A41) and (A42) into the first order condition in (A40) and solving yields the following expression for the politically-motivated bilateral tariff:

$$\tau^h_{xj} = 1 + \frac{1}{\epsilon^j_{xh}}\left(1 + \frac{\delta^{PE}_x q^h_x}{|\lambda^h_{xj}|E^j_{xh}} - (1+\delta^{DVA}_x)\varepsilon^{rj}_{xh}\frac{DVA^j_{xh}}{p^j_x E^j_{xh}} - \frac{(1-\delta^{FVA}_{x*})\varepsilon^{rh}_{x*}}{|\lambda^h_{xj}|}\frac{FVA^h_x}{p^h_x E^j_{xh}} - \tilde{\Omega}_{xj}\right). \quad \text{(A43)}$$

Where $\lambda^h_{xj} \equiv \frac{d\tilde{p}^j_x}{d\tau^h_{xj}} / \frac{dp^h_x}{d\tau^h_{xj}} < 0$, E^j_{xh} is country j's exports of x to Home, $\epsilon^j_{xh} \equiv \frac{dE^j_{xh}}{dp^j_x}\frac{p^j_x}{E^j_{xh}} > 0$ represents bilateral, sector-specific export supply elasticity between country j and Home, and $\tilde{\Omega}_{xj} \equiv \frac{\Omega^R_{xj}+\Omega^{DVA}_{xj}}{(dp^j_x/d\tau^h_{xj})E^j_{xh}}$ captures any potential third-country effects of trade diversion.[13]

B Empirical Appendix

This appendix presents the data we use and collects supplemental empirical results.

B.1 Value-Added Content

Our approach to measuring domestic and foreign value-added content in final goods is an application of the 'global value chain income' decomposition developed in Los, Timmer and de Vries (2015). We explain the method briefly here.

Let II_t be an input shipments matrix, with $(S \times S)$ dimensional block elements $II_{ijt}(s, s')$ that record the value of inputs from sector s in country i used by sector s' in country j. Then, rewrite these matrices in share form, such that A_{ijt} is a $(S \times S)$ matrix with elements $A_{ijt}(s, s') = II_{ijt}(s, s')/Y_j(s')$, which record the share of inputs from sector s in country i used by sector s' in country j as a share of gross output $(Y_j(s'))$ in sector s' in country j. Finally, assemble the block elements $\{A_{ijt}\}$ into the global input-output matrix A_t.

[12] $\Omega^{DVA}_{xj} \equiv \sum_{c\neq h,j} \frac{dDVA^c_{xh}}{dp^c_x}\frac{dp^c_x}{d\tau^h_{xj}} = \sum_{c\neq h,j}\varepsilon^{rc}_{xh}\frac{DVA^c_{xh}}{p^c_x}\frac{dp^c_x}{d\tau^h_{xj}}$. As noted earlier, such third-country effects are generally ambiguous and depend on trade diversion.

[13] This bilateral tariff expression describes country i's non-cooperative equilibrium response as a function of all other countries' tariff policies, which are implicitly captured in the trade volume, elasticity, price, and λ terms. Country i's Nash equilibrium tariff is then given by Equation (A43) evaluated at the world tariff vector for which every country's tariff reaction curves intersect.

Let f_{it} be a $(S \times 1)$ vector with elements equal to the value of final goods produced in each sector in country i, and stack these into a $(SC \times 1)$ vector f_t. Then compute: $Y_t \equiv [I - A_t]^{-1} diag(f_t)$, where $[I - A_t]^{-1}$ is the Leontief inverse of the global input-output matrix. Breaking this down, Y_t contains block elements Y_{ijt} which are $S \times S$ matrices describing how much output from country i is used (directly or indirectly) to produce final goods in country j. Each sub-component $Y_{ijt}(s, s')$ is the value of output from industry s in country i used in producing final output in industry s' in country j.

These output requirements can be translated into value-added content requirements if we know the value added to output ratios in each sector s and source country i: $R_{it}(s)$. The total amount of value added from country i embodied in country j's production in a particular industry $s \in \mathcal{S}$ is: $VA^j_{sit} \equiv \sum_{s'} R_{it}(s') Y_{ijt}(s', s)$. We use these value added elements to construct proxies for country i's domestic value added embodied in foreign production of each sector $s \in \mathcal{S}$ in trading partner $j \neq i \in \mathcal{C}$: $DVA^j_{sit} \equiv VA^j_{sit}$. We also compute the foreign value added embodied in country i's domestic production of s: $FVA^i_{st} \equiv \sum_{c \neq i \in \mathcal{C}} VA^i_{sct}$.

To implement these calculations, we obtain data from the World Input-Output Database.[14] The full set of industries and countries is listed in Table B1. One complication in using these data is that there are two vintages of the database. The WIOD Release 2013 database contains an annual sequence of global input-output tables for the 1995-2011 period covering 35 industries across 27 EU countries and 13 other major countries.[15] We augment this base data set using the WIOD Release 2016 data, which covers 2000-2014 period.

Because the Release 2013 and Release 2016 data are not fully compatible data sources, they do not agree exactly in overlapping years. We treat value-added contents computed using the Release 2013 data as the authoritative data for 1995-2010. We then separately compute value-added contents for 2010-2014 using data from Release 2016. Using 2010-2014 growth rates, we then extrapolate levels from the Release 2013 data forward in time.[16] For final goods, we use trade shares from 2014, together with the total production levels consistent with extrapolation of the value-added contents, to measure final goods trade in 2014. A second technical issue concerns the EU. In both data sets, EU members are reported as individual countries. We compute value-added content using disaggregated country data,

[14]See `http://www.wiod.org`, Dietzenbacher et al. (2013), and Timmer et al. (2015).

[15]Two industries – Mining and Quarrying, Coke, Refined Petroleum and Nuclear Fuel – are excluded as downstream industries in our tariff analysis sample. They are are included as upstream industries in value-added content calculations, however.

[16]In executing this linking procedure, we also map Release 2016 industries into Revision 2013. While Release 2016 has slightly more disaggregated data than Release 2013, such that the sector mapping is many to one in almost all cases, there is one case where it is not. In Release 2016, the Textiles and Leather and Footwear sectors are pooled together, while they are reported separately in Release 2013. We thus apply growth rates for the pooled sector to extrapolate forward the two individual sectors in the Release 2013 data.

Table B1: Industry and Country Coverage

Industries		Countries	
Name	No.	Name	Abbrev.
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
Chemicals and Chemical Products	9	Indonesia	IDN
Rubber and Plastics	10	Japan	JPN
Other Non-Metallic Mineral	11	Mexico	MEX
Basic Metals and Fabricated Metal	12	Russia	RUS
Machinery, NEC	13	South Korea	KOR
Electrical and Optical Equipment	14	Taiwan	TWN
Transport Equipment	15	Turkey	TUR
Manufacturing, NEC	16	United States	USA

Note: Industry numbers denote WIOD (Release 2013) industries. We exclude Mining and Quarrying (WIOD industry 2) and Coke, Refined Petroleum and Nuclear Fuel (WIOD industry 8) in all our analysis.

and then we aggregate value-added contents across EU countries to form the EU composite in our data.

B.2 Tariffs

As noted in Section 2.3, we draw tariff data from UNCTAD (TRAINS) and the WTO via the WITS website [http://wits.worldbank.org]. Multilateral MFN applied tariffs are typically available in the WTO data, while bilateral applied tariffs are from TRAINS. We faced a number of challenges in transforming these raw data sources into a consistent set of tariff measures. Below we describe our procedure to clean and aggregate the tariff data.

First, there are a handful of instances in which a country's entire bilateral tariff schedule is missing in one of our benchmark years. When we can be confident that there were no major trade policy changes in that year, we take the tariff schedule from the closest available year for that country. In a few instances, we instead exclude the importer in that particular year: China (1995, 2000), South Korea (1995, 2000), Taiwan (1995, 2000), and Russia (2000). These countries are included as *exporters* in all years.

Second, there are cases where tariffs are misreported, or entirely missing, for a subset of products or partners in a given year. In some instances, we are able to resolve these idiosyncratic problems through inspection. For example, a country's data may omit a particular tariff preference program in a given year, even though that program exists in the country's data in the years immediately before and after the missing year. While it is possible that these programs were temporarily suspended, our investigative efforts to validate such possible temporary suspensions typically uncovered no corroborating evidence consistent with a genuine change in policy. Therefore, we use information on preferences from surrounding years. In a handful of other cases in which we cannot resolve these problems, we instead record tariffs as missing.

Third, tariff lines (products) are not defined consistently across countries at the most disaggregated (HS-8+) level. Therefore, we take the unweighted mean across (HS-8+) tariff lines within each HS 6-digit Harmonized System category, which are standardized across countries.

Fourth, some HS 6-digit tariff lines have multiple preferences recorded in the data. For example, Canada may report two tariffs for imports from Mexico: one under NAFTA and another under GSP. When one of the reported tariffs derives from an Article XXIV free trade agreement or customs union, we treat that tariff as the applicable tariff. When two or more non-FTA/CU tariffs are present, we adopt the lower of the two rates as the applicable tariff. In the end, we have information on the preference scheme under which every bilateral preferential tariff is offered in the data.[17]

Fifth, there are several technical issues that need to be addressed pertaining to exit/entry of HS 6-digit codes in the data (either over time or across countries at a given point in time) and non-ad valorem tariffs. We start with a data set that includes all available HS 6-digit tariffs. We then refine the data in two dimensions. First, we discard all HS 6-digit sectors (by importer) in which tariffs are applied exclusively as specific duties, in order to avoid converting specific tariffs to ad valorem equivalents. Second, we compute average tariffs using all HS 6-digit categories for which there are ad valorem tariffs at a given point in time, regardless of whether these categories enter or exit the data over time (i.e., we use the full, unbalanced panel of tariffs).

To identify final goods tariffs in the data and link HS categories to WIOD industries, we use a correspondence (the "BTDIxE conversion key") from the OECD Structural Analysis (STAN) Database.[18] It builds on the Broad Economic Categories (BEC) classification to link HS codes to end use categories, and we retain HS 6-digit categories classified as consumption and capital goods. We also retain specialized mixed use categories defined by the OECD for mobile phones, medical goods, computers, and autos, since these have important final use segments. Roughly forty percent of the HS 6-digit codes in the raw data are classified

[17] One hurdle to identifying preference programs is that program identifiers in the raw UNCTAD/TRAINS data are sometimes difficult to parse. When necessary, we cross-reference various secondary sources to identify the relevant preference schemes.

[18] See https://stats.oecd.org/Index.aspx?DataSetCode=BTDIxE_i4.

as final goods, which roughly corresponds to the value share of final goods in world trade. We concord HS categories to WIOD industries using a cross-walk from HS codes to ISIC (Revision 3) industries to WIOD industry codes.

We aggregate HS 6-digit tariffs to the WIOD industry level using simple averages, which yields measures for applied bilateral and MFN tariffs at the importer-exporter-industry-year level. Mechanically, a bilateral country pair has preferential tariff in a given industry and year if *any* bilateral applied HS 6-digit tariff for that importer-exporter-industry-year cell is below the MFN applied rate. Typically, the preference scheme in each cell is unique, and so we record the relevant program as the source of the tariff preferences at the industry level. For a small handful of cells, there are multiple preference schemes active within a given bilateral-industry-year cell (some HS 6-digit tariff lines within the industry receive preferences under one program, while others receive preferences under a different program). In these cases, we record the more important preference program, which typically accounts for the vast majority of preferences in the industry.

Sources of Tariff Preferences As noted in the main text, there are preferential tariffs in 30-40% of the importer-exporter-industry-year cells in our data. The GSP program accounts for the largest share of preferences.[19] There are three sources of discretion in the GSP program captured in our data. First, each GSP granting country chooses the set of countries to which to grant GSP access. Second, each GSP granting country chooses the set of industries covered by GSP. Third, the importing country chooses the level of the GSP tariff to apply to its GSP-partners.[20] Each of these decisions is updated over time, as countries introduce or renew their GSP programs.[21] Bilateral trade agreements, partial scope agreements adopted under the WTO's Enabling Clause, and other miscellaneous preference programs make up the remainder of preferences in our data. The miscellaneous preferences are difficult to classify concisely. For example, one of the largest miscellaneous preference programs we observe is the "Australia Tariff" in Canada's tariff schedule, under which Canada affords Australia preferential treatment for roughly 300 HS 6-digit categories. Other idiosyncratic preference schemes are more limited, sometimes covering only a few miscellaneous HS 6-digit tariff lines.

[19]For our country sample, GSP-granting countries include Australia, Canada, the EU, Japan, Russia, Turkey, and the United States. Recipients include Brazil, China, India, Indonesia, South Korea, Mexico, Russia, Turkey, and Taiwan.

[20]As we aggregate from HS 6-digit categories to WIOD industries, average industry-level tariffs reflect both the set of HS 6-digit categories that receive tariff preferences and the size of those tariff preferences.

[21]In our data, GSP tariffs do not vary across exporters included in a given importer's GSP program at the HS 6-digit level (with a few exceptions). In reality, countries often discriminate across exporters within their GSP program. For example, Blanchard and Hakobyan (2014) review the vagaries of country-product exclusions in the United States GSP program. Since these are not captured in our data source, our data understates the degree of discretion with which the GSP program is applied in practice.

Table B2: Classifying Trade Agreements

	Years in Force	Asymmetric Phase-in	WTO Notification
Bilateral Agreements			
Australia-Indonesia	2015	2015	Art. XXIV
Australia-Japan	2015	2015	Art. XXIV
Australia-South Korea	2015	2015	Art. XXIV
Australia-United States	2005, 2010, 2015	2005	Art. XXIV
Brazil-Mexico	2005, 2010, 2015		Enabling Clause
Canada-South Korea	2015		Art. XXIV
China-Indonesia	2005, 2010, 2015		Enabling Clause
European Union-Mexico	2000, 2005, 2010, 2015	2000	Art. XXIV
European Union-South Korea	2015	2015	Art. XXIV
European Union-Turkey	2000, 2005, 2010, 2015		Art. XXIV
India-Indonesia	2010, 2015	2010	Enabling Clause
India-Japan	2015		Art. XXIV
India-South Korea	2015		Article XXIV/Enabling Clause
Indonesia-Japan	2010, 2015	2010, 2015	Art. XXIV
Indonesia-South Korea	2010, 2015	2010	Art. XXIV/Enabling Clause
Japan-Mexico	2005, 2010, 2015	2005	Art. XXIV
South Korea-Turkey	2015		Art. XXIV
South Korea-United States	2015		Art. XXIV
Regional Agreements			
Asia-Pacific Trade Agreement	2005, 2010, 2015		Enabling Clause
Global System of Trade Preferences	1995, 2000, 2005, 2010, 2015		Enabling Clause
NAFTA (Canada-Mexico-United States)	1995, 2000, 2005, 2010, 2015		Art. XXIV

Note: Asia-Pacific Trade Agreement includes China, India, and South Korea (among others). Global System of Trade Preferences includes Brazil, India, Indonesia, Mexico, and South Korea (among others). The North American Free Trade Agreement (NAFTA) includes Canada, Mexico, and the United States.

Turning to bilateral trade agreements, we classify these preference programs into two groups: *potentially* reciprocal trade agreements (RTAs) and non-reciprocal trade agreements.[22] We define country i to have a potentially reciprocal trade agreement ($RTA_{ijt} = 1$) with country j in year t if those countries have a trade agreement in force that was notified to the WTO under Article XXIV, and $RTA_{ijt} = 0$ otherwise.[23] These are commonly referred to as Customs Unions and Free Trade Areas, and Article XXIV mandates that these agreements eliminate tariffs/duties on 'substantially all trade'. We classify remaining trade agreements as non-reciprocal. These agreements are exclusively struck between developing countries; most are notified to the WTO under the Enabling Clause, so they are not bound by the 'substantially all trade' requirement of Article XXIV. The data confirm that these agreements are narrower in scope, often with HS 6-digit coverage rates of less than 20 percent, compared to over 90 percent for RTAs. Reflecting this, two of these agreements (the

[22]The WTO refers to all WTO-notified agreements as 'reciprocal' in that they involve the exchange of tariff preferences. We instead take 'reciprocal' to mean a sufficiently comprehensive exchange of tariff preferences that nullifies bilateral terms-of-trade externalities within the agreement.

[23]Some agreements are phased in over time, in an asymmetric manner, possibly due to political economy considerations. How we treat asymmetric phase-in is not critical for the results.

Asia-Pacific Trade Agreement and the Global System of Trade Preferences) are commonly referred to as "partial scope" agreements. Table B2 lists the trade agreements in our data, years they are in force, years they are asymmetrically phased in, and the way in which they are notified to the WTO.

B.3 Temporary Trade Barriers

For temporary trade barriers, we obtain data from the World Bank's Temporary Trade Barriers Database [Bown (2016)].[24] In the raw data, antidumping and countervailing duties (CVDs) are explicitly partner- and product-specific. While safeguards are applied at the product level, they take on an exporter-specific dimension via country-level exclusions. As described in Bown (2011), antidumping and safeguards were the most heavily used of the policies for our countries during this sample period. Furthermore, in the handful of cases in which CVDs were utilized, they were typically applied concurrently (for the same products and exporters) with antidumping duties [Bown (2011, pp. 1989-1990)], so that our measures of TTBs would not be substantially affected by dropping CVDs.

As in the tariff data, we begin with TTB data at the product-level, aggregate to the HS 6-digit level, extract HS categories that correspond to final goods, and then aggregate to WIOD industries. The TTB coverage ratio is the (unweighted) share of HS 6-digit final goods products within a WIOD sector for which a given importing country has a TTB in effect against a particular trading partner in a given year.

Coverage ratios are a convenient tool for aggregating TTBs across products and measuring their overall intensity, which avoids needing to convert heterogeneous TTB measures (e.g., ad valorem duties, specific duties, price undertakings, or quantitative restrictions) into ad valorem equivalents. For emphasis, the coverage ratio measures the stock of TTBs in force, not the flow of newly imposed TTBs. Further, the stock measure accounts for removal of TTBs as they expire.

B.4 Supplemental Discussion for Empirical Results

In this section, we discuss details about how we measure upstream production differentiation, and we provide additional results about how preferences are related to value-added content across different trade policy regimes.

[24] It is available at https://www.chadpbown.com/temporary-trade-barriers-database/.

B.4.1 Measuring Upstream Differentiation

In Section 2.3.2, we presented results about heterogeneity in the impact of domestic content in foreign production on tariffs, depending on the degree of upstream differentiation. To formalize the motivation, let ν_{xh}^{j} now be a bundle of factors $\{\nu_{xh}^{zj}\}$, where z indexes underlying factor types, with associated prices r_{xh}^{zj} and pass-through elasticities $\varepsilon_{xh}^{zj} \equiv \frac{dr_{xh}^{zj}}{dp_x^j}\frac{dp_x^{zj}}{r_{xh}^{zj}}$. Then the bilateral pass-through elasticity is: $\varepsilon_{xh}^{j} = \sum_z \left(\frac{DVA_{xh}^{zj}}{DVA_{xh}^{j}}\right)\varepsilon_{xh}^{zj}$, where $DVA_{xh}^{zj} \equiv r_{xh}^{zj}\upsilon_{xh}^{zj}$.

For empirical measurement, consider two types of factors, where some have high (H) pass-through elasticities and others have low (L) pass-through elasticities: $\{\varepsilon_{sh}^{Hj}, \varepsilon_{sh}^{Lj}\}$. Then the aggregate elasticity may be re-written as:

$$\varepsilon_{xh}^{j} = \varepsilon_{xh}^{Hj}\left(\frac{DVA_{xh}^{Hj}}{DVA_{xh}^{j}}\right) + \varepsilon_{xh}^{Lj}\left(\frac{DVA_{xh}^{Lj}}{DVA_{xh}^{j}}\right), \tag{B1}$$

where $DVA_{xh}^{Hj} \equiv \sum_{z\in H} DVA_{xh}^{zj}$ and $DVA_{xh}^{Lj} = \sum_{z\in L} DVA_{xh}^{zj}$. With this decomposition, the DVA-specific term in the optimal bilateral tariff becomes:

$$\begin{aligned}(1+\delta_{xh}^{*})\varepsilon_{xh}^{j}\frac{DVA_{xh}^{j}}{p_x^j M_{xj}^h} &= (1+\delta_{xh}^{*})\left[\varepsilon_{xh}^{Hj}\left(\frac{DVA_{xh}^{Hj}}{DVA_{xh}^{j}}\right) + \varepsilon_{xh}^{Lj}\left(\frac{DVA_{xh}^{Lj}}{DVA_{xh}^{j}}\right)\right]\frac{DVA_{xh}^{j}}{p_x^j M_{xj}^h} \\ &= (1+\delta_{xh}^{*})\varepsilon_{xh}^{Hj}\frac{DVA_{xh}^{Hj}}{p_x^j M_{xj}^h} + (1+\delta_{xh}^{*})\varepsilon_{xi}^{Lj}\frac{DVA_{xh}^{Lj}}{p_x^j M_{xj}^h}.\end{aligned} \tag{B2}$$

This decomposition motivates our effort to measure DVA_{xh}^{Hj} and DVA_{xh}^{Lj} separately, and then construct $\ln\left(\frac{DVA_{xh}^{Hj}}{p_x^j M_{xj}^h}\right)$ and $\ln\left(\frac{DVA_{xh}^{Lj}}{p_x^j M_{xj}^h}\right)$. Coefficients attached to these separate DVA ratios shed light on underlying pass-through elasticities ε_{xh}^{Hj} versus ε_{xh}^{Lj}.

As discussed in the text, we take two different approaches. The first approach is is to classify manufacturing sectors as differentiated, high pass-through sectors (H) and all other sectors as low pass-through sectors L. Then DVA_{xh}^{Hj} is value added that originates in the manufacturing sector of country h that is used by industry x in country j, and DVA_{xh}^{Lj} is value added from non-manufacturing sectors. The second approach uses the Rauch classification [Rauch (1999)]. Rauch classifies commodities as differentiated or non-differentiated at the SITC 4-digit level. We concord these to WIOD industries, where there are many SITC industries (k) in each WIOD industry. Letting $diff_k = 1$ if SITC category k is differentiated, and 0 otherwise, we the construct the share of underlying SITC categories that are differentiated within each WIOD industry, denoted by z: $diff_z \equiv \frac{1}{K_z}\sum_{k\in z} diff_k$. Then we decompose DVA as follows: $DVA_{xh}^{j} = DVA_{xh}^{Rj} + DVA_{xh}^{(-R)j}$, where $DVA_{xh}^{Rj} = \sum_z diff_z DVA_{xh}^{zj}$ is value added that originates in Rauch-differentiated sectors, and $DVA_{xh}^{-Rj} = DVA_{xh}^{j} - DVA_{xh}^{Rj}$ is value added that originates in non-differentiated sectors.

B.4.2 Heterogeneity by Trade Policy Regime

We start by exploring how content is related to tariffs inside versus outside reciprocal trade agreements. To frame discussion, suppose that two countries, i and j, engage in cooperative bilateral tariff negotiations, and that these negotiations mitigate the influence of bilateral terms-of-trade motives in the resulting RTA [Bagwell and Staiger (1999)].[25] Since the influence of domestic content on optimal tariffs operates through *foreign* final goods prices, eliminating terms-of-trade manipulation would negate the role for DVA in shaping tariffs. In contrast, foreign content embodied in domestic production (FVA) will still shape the structure of tariff preferences even within reciprocal agreements, as long as cooperative agreements do not also eliminate behind-the-border externalities (operating via local price changes).[26]

To explore these effects, we interact DVA and FVA ratios with the RTA indicator to estimate heterogeneous coefficients for preferences set within versus outside RTAs. If RTAs completely neutralize the bilateral terms-of-trade externality, then DVA should not influence tariffs set under RTAs, meaning that the coefficient on the interaction term should be zero. At a minimum, we expect diminished sensitivity of tariffs to DVA if RTAs at least partially neutralize the bilateral terms-of-trade externality. Instead, we expect to find that the coefficient on the FVA ratio is negative for tariffs set both within and outside regional agreements. In Table B3, we find that the coefficient on the DVA ratio within RTAs is not statistically different from zero in any specification, and it is meaningfully smaller than the estimated coefficient outside RTAs across the board. Further, the coefficient on the FVA ratio is negative and significant both within and outside RTAs, consistent with theory. It is striking that FVA effects are so strong inside RTAs, despite the non-importance of DVA effects inside the same set of RTAs.

In Table B4, we focus attention entirely on non-RTA preferences, dropping all observations with $RTA_{hjt} = 1$ from the estimation. In Panel A, we repeat the baseline estimation in this sub-sample. We find negative coefficients attached to the DVA and FVA ratios, although they are attenuated in magnitude in this sample, reflecting the fact that GSP preferences are less generous on average.

In Panel B of Table B4, we explore preference setting under the GSP program versus other (non-RTA) preference programs. We define the set of potential *GSP-granting* countries as those that granted GSP access to at least one other country (at any time) in our

[25] In the limit as the terms of trade motive goes to zero, the government will behave as if $\frac{dp_x^j}{d\tau_{xj}^i} \to 0$.

[26] Even if reciprocal agreements eliminate *bilateral* local price externalities, we might still expect FVA to play a role for RTA tariffs, because the FVA externality is *multilateral* in scope.

Table B3: Heterogeneity by Trade Policy Regime: Regional Trade Agreements

	OLS		Tobit	
	(1)	(2)	(3)	(4)
DVA ratio (outside RTA)	-0.44**	-0.48**	-1.07***	-1.15***
	(0.18)	(0.20)	(0.36)	(0.39)
DVA ratio (inside RTA)	-0.13	-0.16	-0.75	-0.78
	(0.30)	(0.32)	(0.49)	(0.51)
FVA ratio (outside RTA)	-0.55***		-0.52	
	(0.19)		(0.38)	
FVA ratio (inside RTA)	-2.09***		-4.28***	
	(0.70)		(1.26)	
IP ratio (outside RTA)	1.07***		1.80***	
	(0.31)		(0.63)	
IP ratio (inside RTA)	2.54***		5.43***	
	(0.65)		(1.22)	
IP ratio + FVA ratio ($\gamma^{IP} + \gamma^{FVA}$)		0.50		1.22**
		(0.36)		(0.52)
FVA ratio outside − inside RTA		1.62**		3.74**
		(0.77)		(1.49)
Log IIP Ratio Outside − Inside RTA		-1.55***		-3.59***
		(0.59)		(1.30)
IP ratio outside − inside RTA	-6.73***	-6.83***	-13.8***	-13.5***
	(1.43)	(1.51)	(2.68)	(2.70)
Observations	11,385	11,385	11,385	11,385
R-Squared	0.506	0.524		
Column Fixed Effects				
Importer-Year	Y	N	Y	N
Importer-Industry	Y	N	Y	N
Importer-Industry-Year	N	Y	N	Y
Exporter-Industry-Year	Y	Y	Y	Y

Note: $RTA_{hjt} = 1$ if countries h and j have an Article XXIV trade agreement in force, and zero otherwise. Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

sample. Likewise, we define the set of potential *GSP-eligible* countries as those that received GSP access from at least one other country (at any time) in our sample. We then define an indicator that identifies which country pairs are potentially eligible for GSP preferences: $GSP_{ij} = \mathbf{1}\left(i \in \textit{GSP-granting}, j \in \textit{GSP-eligible}\right)$.[27] For country pairs with $GSP_{ij} = 0$, non-GSP preference schemes are the source of observed tariff preferences. Splitting coefficients based on potential GSP eligibility in Panel B, we see find that higher DVA ratios are associated with lower bilateral tariffs both inside and outside the GSP scheme.[28] We also see that higher FVA ratios are associated with lower tariffs among non-GSP country pairs, where partial scope agreements are the most important source of preferences. We do not find significant effects of FVA within GSP-eligible pairs. Recalling that FVA effects are identified in large part based on time variation at the importer-industry level, this is not surprising. The relatively static nature of the GSP program implies there is limited time series variation among this group; further, GSP arrangements are replaced by other agreements over time (see Figure 1a), so attrition works against finding sharp results here.

C Quantitative Model Appendix

This appendix provides details about the quantitative model used in Section 3.

C.1 Elements of the Framework

Given prices and income, the representative consumer chooses consumption of the numeraire and differentiated goods to solve:

$$\max_{d_0^h, \{d_c^h\}_{c \in C}} d_0^h + \delta^h \left(d^h\right)^{\psi} \quad \text{s.t.} \quad I^h = d_0^h + \sum_{c=1}^{C} p_c^h d_c^h \tag{C1}$$

where $d^h = \left(\sum_{c=1}^{C} \left(d_c^h\right)^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)}$. The consumer's first order conditions imply demands: $d^h = \left(\frac{p^h}{\delta^h \psi}\right)^{1/(\psi-1)}$ and $d_c^h = \left(\frac{p_c^h}{p^h}\right)^{-\sigma} d^h$, where the price index for the composite good is defined as: $p^h = \left(\sum_{c=1}^{C} \left(p_c^h\right)^{1-\sigma}\right)^{1/(1-\sigma)}$.

[27] For country pairs with $GSP_{ij} = 1$, the GSP program itself accounts for essentially all observed preferences in this non-RTA subsample of the data, in large part because advanced countries have limited scope under WTO rules to confer preferences outside of RTAs. However, many pairs with $GSP_{ij} = 1$ have no recorded bilateral preferences (i.e., j receives MFN treatment from i), because some potentially GSP eligible exporters are excluded by GSP-granting countries.

[28] For GSP-eligible pairs, this pattern is apparent only when we adjust for censoring, which is quite sensible given that the advanced countries that grant GSP preferences generally also have very low MFN tariff bindings; thus there is strong censoring in this subset of the data.

Table B4: Heterogeneity by Trade Policy Regime: Non-RTA Preferences

Panel A: No RTA Sample				
	OLS		Tobit	
	(1)	(2)	(3)	(4)
DVA ratio	-0.15**	-0.17**	-0.59***	-0.66***
	(0.061)	(0.070)	(0.21)	(0.24)
FVA ratio	-0.39***		-0.46	
	(0.13)		(0.28)	
IP ratio	0.64***		1.40***	
	(0.15)		(0.43)	
IP ratio + FVA ratio ($\gamma^{IP} + \gamma^{FVA}$)		0.28***		1.04***
		(0.074)		(0.28)
Observations	10,210	10,210	10,210	10,210
R-Squared	0.391	0.425		

Panel B: Heterogeneous Coefficients by GSP Eligibility				
	OLS		Tobit	
	(5)	(6)	(7)	(8)
DVA ratio (GSP Ineligible)	-0.18***	-0.20***	-0.84***	-0.91**
	(0.065)	(0.072)	(0.32)	(0.35)
DVA ratio (GSP Eligible)	-0.10	-0.12	-0.65***	-0.73***
	(0.071)	(0.080)	(0.21)	(0.24)
FVA ratio (GSP Ineligible)	-0.57***		-3.61***	
	(0.16)		(1.09)	
FVA ratio (GSP Eligible)	-0.11		0.21	
	(0.17)		(0.31)	
IP ratio (GSP Ineligible)	0.85***		5.08***	
	(0.20)		(1.20)	
IP ratio (GSP Eligible)	0.28*		0.61	
	(0.17)		(0.41)	
IP ratio + FVA ratio		0.20**		0.91***
		(0.084)		(0.27)
FVA ratio Outside − Inside GSP		-0.51**		-4.52***
		(0.20)		(1.46)
IP ratio Outside − Inside GSP		0.61***		5.22***
		(0.22)		(1.50)
GSP Eligibility	1.11*	1.20*	28.7***	29.3***
	(0.66)	(0.68)	(4.55)	(5.02)
Observations	10,210	10,210	10,210	10,210
R-Squared	0.401	0.436		
Column Fixed Effects				
Importer-Year	Y	N	Y	N
Importer-Industry	Y	N	Y	N
Importer-Industry-Year	N	Y	N	Y
Exporter-Industry-Year	Y	Y	Y	Y

Note: GSP eligibility is an indicator for whether country h could grant country j GSP preferences, and zero otherwise. Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

As described in the main text, each agent ($i \in (0,1)$) is endowed with $N^h(i)$ units of the GVC input, and the effective units of the factor supplied by agent i to producers in destination c is given by $z_h^c(i)N^h(i)$, where $z_h^c(i)$ is the agent's productivity draw. The vector of efficiency draws for agent i is: $\mathbf{z}_h(i) \equiv \{z_h^c(i)\}_c$. These efficiencies are drawn independently across agents and destinations from Frèchet distributions (see the text), and let us denote the joint distribution of draws for country-h agents as $F_h(\mathbf{z})$.

The set of efficiency draws for which c is the highest return destination to which to supply the input is $\Omega \equiv \left\{\mathbf{z} \text{ s.t. } \bar{r}_h^c z_h^c \geq \bar{r}_h^d z_h^d \text{ for all } d\right\}$, where $\bar{r}_h^c$ are the prices for each efficiency unit of the GVC input supplied by agents from h to destination c. The probability that the agent has the highest payoff in destination c is:

$$\pi_h^c = \Pr\left(\bar{r}_h^c Z_h^c \geq \max_{d \neq c}\left\{\bar{r}_h^d Z_h^d\right\}\right) = \int_\Omega dF_h(\mathbf{z}) = A_h^c\left(\frac{\bar{r}_h^c}{\Phi^h}\right)^\theta, \tag{C2}$$

where $\Phi^h = \left(\sum_d A_h^d \left(\bar{r}_c^d\right)^\theta\right)^{1/\theta}$. The effective units of the input supplied by all agents to destination c is then:

$$\bar{\nu}_h^c \equiv N^h \pi_h^c \mathbf{E}\left[z_h^c | \bar{r}_h^c z_h^c \geq \max_{d \neq h}\left\{\bar{r}_h^d z_h^d\right\}\right] = \Gamma\left(1 - \frac{1}{\theta}\right) A_h^c \left(\frac{\bar{r}_h^c}{\Phi^h}\right)^{\theta - 1} N^h \tag{C3}$$

Total income accruing to each agent, and income for the representative consumer, are defined the main text.

As described in the text, competitive producers in h combine GVC inputs with labor via the production function: $q^h = z^h\left(\sum_c \left(\nu_c^h\right)^{(\varrho-1)/\varrho}\right)^{\alpha\varrho/(\varrho-1)}\left(l^h\right)^{1-\alpha}$. Cost minimization implies demand for GVC inputs is: $r_c^h \nu_c^h = \left(\frac{r_c^h}{r^h}\right)^{1-\varrho} \alpha \bar{p}^h q^h$, with $r^h = \left(\sum_c \left(r_c^h\right)^{1-\varrho}\right)^{1/(1-\varrho)}$ and $r_c^h = \kappa_c^h \bar{r}_c^h$. Here $\bar{p}^h$ is the price the producer receives for their output. Demand for labor satisfies: $l^h = (1-\alpha)\,\bar{p}^h q^h / w^h$, w^h is the price of labor.

Turning to define the government's objective, welfare for the representative consumer is:

$$V^h = d_0^h + \delta^h \left(d^h\right)^\psi = I^h + \left(\frac{1}{\psi} - 1\right) E^h, \tag{C4}$$

where we have substituted using the budget constraint the consumer's first order conditions, and $E^h = p^h d^h$ is consumer expenditure on differentiated goods. Then, the government objective is:

$$G^h = V^h + \delta^{DPE}\pi^h + \delta^{DVA} DVA^h + \delta^{FVA} FVA^h, \tag{C5}$$

where $\pi^h = \alpha \bar{p}^h q^h$ is the payments accruing to GVC inputs used in production in country h, $DVA^h = \sum_{c \neq h} \bar{r}_h^c \bar{\nu}_h^c$ is the value of payments to GVC inputs from country h used in all foreign destinations ($c \neq h$), and $FVA^h = \sum_{c \neq h} \bar{r}_c^h \bar{\nu}_c^h$ is the value of payments to foreign GVC inputs used in production in country h. Taking foreign tariffs as given, the home government chooses $\{t_c^h\}_{c \neq h}$ to maximize G^h, subject $t_c^h \leq t_{MFN}^h$ and model equilibrium conditions.

C.2 Solving for Optimal Tariffs

Following Ossa (2014), we solve for optimal tariffs using a MPEC (mathematical program with equilibrium constraints) routine.[29] Further, to simplify parameterization of the problem, we write the objective and equilibrium constraints using exact hat algebra. For variable x, let $\hat{X} = \frac{1+\tilde{x}}{1+x}$, where $\tilde{x}$ denotes the value at the optimum and x is the value in the baseline (observed) equilibrium. We define bilateral flows for final goods as $X_c^h = \bar{p}^c \tau_c^h d_c^h$, bilateral flows of GVC inputs as $V_c^h = \bar{r}_c^h \kappa_c^h \nu_c^h$, and the value of output as $Y^h = \bar{p}^h q^h$.

The optimal policy for country h then solves the following problem:

$$\max_{\left\{\{\hat{T}_c^h\}_{c \neq h}, \hat{\bar{r}}_c^d\right\}} \quad \hat{G}^h \tag{C6}$$

$$\text{s.t.} \quad \hat{A}_c^d \left(\hat{\bar{r}}_c^d\right)^{\theta} \left(\hat{\Phi}^c\right)^{1-\theta} \hat{N}^c = \left(\frac{\hat{\kappa}_c^d \hat{\bar{r}}_c^d}{\hat{\bar{r}}^d}\right)^{1-\varrho} \hat{Y}^d \tag{C7}$$

$$\frac{1}{1+t_c^h} \leq \hat{T}_c^h \leq \frac{1+t_{MFN}^h}{1+t_c^h} \tag{C8}$$

where the government's objective function is given by:

$$\hat{G}^h = \left(\frac{U^h}{G^h}\right)\hat{U}^h + \left[\frac{\delta^{DPE}\pi^h}{G^h}\right]\hat{Y}^h + \left[\frac{\delta^{DVA}DVA_h}{G^h}\right]\widehat{DVA}_h + \left[\frac{\delta^{FVA}FVA^h}{G^h}\right]\widehat{FVA}^h \tag{C9}$$

$$\hat{U}^h = \left(\frac{I^h}{U^h}\right)\hat{I}^h + \left(\frac{E^h}{U^h}\right)\left(\frac{1}{\psi} - 1\right)\hat{E}^h \tag{C10}$$

$$\hat{I}^h = \left(\frac{w^h L^h}{I^h}\right)\hat{w}^h \hat{L}^h + \sum_c \left(\frac{V_h^c}{I^h}\right)\hat{V}_h^c + \sum_{c \neq h}\left(\frac{\tilde{t}_c^h X_c^h}{I^h}\right)\hat{X}_c^h + \left(\frac{\tilde{B}^h}{I^h}\right) \tag{C11}$$

$$\widehat{DVA}_h = \sum_{c \neq h}\left(\frac{V_h^c}{DVA_h}\right)\hat{V}_h^c \tag{C12}$$

$$\widehat{FVA}^h = \sum_{c \neq h}\left(\frac{V_c^h}{FVA^h}\right)\hat{V}_c^h. \tag{C13}$$

[29] We solve for unilaterally optimal tariffs, whereas Ossa (2014) solves for tariffs in a Nash equilibrium of the non-cooperative policy game. We compute unilaterally optimal tariffs to maintain consistency with the prior segments of the paper, and to speed up computation.

The optimal tariff is $\tilde{t}^h_c = \left(1 + t^h_c\right) \hat{T}^h_c - 1$, where $\hat{T}^h_c$ solves the MPEC problem and t^h_c is the tariff in the initial equilibrium. $\tilde{B}^h$ is an exogenously chosen value for the trade balance in the counterfactual equilibrium; we hold the trade balance constant at its initial value, so $\tilde{B}^h = B^h$. The first constraint (Equation (C7)) equates bilateral demand and supply of GVC inputs, and the second (Equation (C8)) reflects the MFN rule and a non-negativity constraint on tariffs.

Given $\left\{\hat{T}^d_c, \hat{\bar{r}}^d_c\right\}$, the following equilibrium conditions are used to solve for $\left\{\hat{p}^d, \hat{\bar{p}}^d, \hat{r}^d, \hat{\Phi}^c\right\}$ and $\left\{\hat{X}^d_c, \hat{V}^d_c, \hat{E}^d, \hat{Y}^d\right\}$, which are needed to evaluate the objective and constraints:

$$\hat{T}^d_c \hat{X}^d_c = \left(\frac{\hat{T}^d_c \hat{\tau}^d_c \hat{\bar{p}}^c}{\hat{p}^d}\right)^{1-\sigma} \hat{E}^d \tag{C14}$$

$$\hat{E}^d = \left(\hat{p}^d\right)^{\psi/(\psi-1)} \left(\hat{\delta}^d\right)^{1/(1-\psi)} \tag{C15}$$

$$\hat{\bar{p}}^c = \left[\hat{z}^c\right]^{-1} \left(\hat{w}^c\right)^{1-\alpha} \left(\hat{r}^c\right)^{\alpha} \tag{C16}$$

$$\hat{p}^d = \left(\sum_{c=1}^{C} \left(\frac{\left(1 + t^d_c\right) X^d_c}{E^d}\right) \left(\hat{T}^d_c \hat{\tau}^d_c \hat{\bar{p}}^c\right)^{1-\sigma}\right)^{1/(1-\sigma)} \tag{C17}$$

$$\hat{r}^d = \left(\sum_{c=1}^{C} \left(\frac{V^d_c}{\alpha Y^d}\right) \left(\hat{\kappa}^d_c \hat{\bar{r}}^d_c\right)^{1-\varrho}\right)^{1/(1-\varrho)} \tag{C18}$$

$$\hat{\Phi}^c = \left(\sum_{d=1}^{C} \left(\frac{V^d_c}{\sum_d V^d_c}\right) \hat{A}^d_c \left(\hat{\bar{r}}^d_c\right)^{\theta}\right)^{1/\theta} \tag{C19}$$

$$\hat{Y}^d = \sum_{c=1}^{C} \left(\frac{X^c_d}{Y^d}\right) \hat{X}^c_d. \tag{C20}$$

C.3 Calibration

We calibrate the model to solve for tariffs in the composite goods sector, which is an aggregate of the fourteen sectors used in our empirical analysis. We construct tariffs for the baseline equilibrium ($\left\{t^h_c, t^h_{MFN}\right\}$) by taking simple averages of bilateral applied tariffs and MFN tariffs across sectors. Values for final goods trade and value-added content are summed across sectors to obtain $\left\{X^h_c, VA^h_c\right\}$. Using WIOD data, we also compute aggregate gross domestic product (GDP^h) and expenditure (GNE^h), which include the fourteen goods sectors plus natural resources and services sectors.

Using this data, total output of the differentiated good is $Y^h = \sum_c X^c_h$. As measured in data, VA^h_h includes both domestic content attributable to GVC inputs and homogenous factors sourced by h from itself. Therefore, we define $V^h_h = VA^h_h - (1-\alpha) Y^h$, where

$(1-\alpha) Y^h$ is the value of payments to the domestic homogeneous factor used in goods production. When $c \neq h$, $V_c^h = VA_c^h$. Transfers across countries are $B^h = GNE^h - GDP^h$. Income for homogeneous inputs is $w^h L^h = GDP^h - \sum_c V_h^c$. Tariff revenue is $R^h = \sum_{c \neq h} t_c^h X_c^h$, income is $I^h = w^h L^h + \sum_c V_h^c + R^h + B^h$, and indirect utility is $V^h = I^h + \left(\frac{1}{\psi} - 1\right) E^h$. The government objective is $G^h = U^h + \delta^{DPE} \pi^h + \delta^{DVA} DVA^h + \delta^{FVA} FVA^h$, with $DVA^h = \sum_{c \neq h} V_h^c$, $FVA^h = \sum_{c \neq h} V_c^h$, and $\pi^h = \alpha Y^h$.

We present externally calibrated parameters in the main text. As noted there, we calibrate the weights on domestic political economy (δ^{DPE}) and DVA (δ^{DVA}) to match data moments. Two moments are obtained by regressing t_c^h on the log DVA ratio – $\ln\left(V_c^h / X_c^h\right)$ – and log bilateral imports – $\ln X_c^h$ – controlling for importer-industry and exporter-industry fixed effects. This specification corresponds to column (2) in Table 1, and the resulting coefficients are -1.5 for DVA and -1.74 for imports. In the model, we compute equilibrium trade flows assuming all countries impose unilaterally optimal tariffs, and then replicate this regression on the simulated data to form simulated moments. In addition, we compute the correlation of optimal tariff preferences and observed tariff preferences, conditional on the observed tariff preference being nonzero. We then grid search for values of δ^{DPE} and δ^{DVA} that minimize the unweighted sum of squared deviations between model and data moments.[30] We compute values of the objective over $\delta^{DPE} \in [.5, 3.5]$ with grid points spaced at intervals of 0.25 and $\delta^{DVA} \in [1, 13]$ with grid points at intervals of 0.5. The objective function tightly identifies δ^{DPE}; while it has less curvature in δ^{DVA}, there is also a clear minimum.

With calibrated parameters, regressions using simulated values for optimal tariffs and value-added contents yield coefficients of -1.40 for the DVA coefficient and -1.20 for the import coefficient, so the model hits these targeted moments reasonably well. Further, the correlation between observed and actual preferences (conditional on actual preferences being nonzero) is 0.33.

Turning to untargeted moments, the mean preference in the model is 4.6 percentage points. In the data, the mean preference is 0.8 percentage points; the mean preference is 2.1 percentage points, conditional on the observed preference being nonzero. This gap between mean preferences in the model versus data is attributable (in part) to the fact that the model over-predicts the incidence of preferences. That is, there are many importer-exporter cells for which there are no observed preferences, where the model indicates there should be preferences granted. One reason for this is that the model lacks idiosyncratic factors that make countries reluctant to offer preferences.[31] A second reason is that there

[30] The third moment is a correlation between model and data, so the third entry in the objective function is the difference between this correlation and one.

[31] For example, no countries offer tariff preferences to Russia, which could be explained by international political considerations not included in the model.

are institutional constraints on policy, which our model does not capture. A third reason is that GVC integration is rising over time, and it may take time for countries to adjust their preferences schemes in response. The structural model lacks the degrees of freedom need to capture these ideas. Further, while raising the importance of political economy considerations would reduce the incidence of preferences, it also deteriorates model fit for actual observed preferences.

As a final element of the calibration, we implement counterfactuals that examine changes in parameters that are consistent with historical data. We obtain these parameters by inverting the model. As data inputs, we compute the ratios of the value of bilateral trade across years: $\left\{\hat{X}_{ct}^d, \hat{V}_{ct}^d\right\}$, where $t = \{1995, 2015\}$ and the base year is 2005. We also measure observed tariff changes using our data: $\{\hat{T}_{ct}^d\}$ for $t = \{1995, 2015\}$. Noting that these data include both internal ($c = d$) and international ($c \neq d$) trade, we can then recover $2 \times C^2$ parameters. We normalize internal iceberg trade costs to one, as is standard: $\hat{\tau}_{ct}^c = \hat{\kappa}_{ct}^c = 1$. We also set $\hat{z}_t^c = 1$ and $\hat{A}_{ct}^d = 1$, as well as $\hat{w}_t^c = 1$, which implies there is no productivity growth in production of the numéraire good.

The model equilibrium conditions can then be inverted to recover the parameters $\left\{\hat{\tau}_{ct}^d, \hat{\kappa}_{ct}^d\right\}_{c\neq d}$ and $\left\{\hat{\delta}_t^h, \hat{N}_t^c\right\}$. The final goods equilibrium conditions can be combined to yield:

$$\frac{\hat{T}_{ct}^d \hat{X}_{ct}^d}{\hat{E}_t^d} = \frac{\left(\hat{T}_{ct}^d \hat{\tau}_{ct}^d \hat{\tilde{p}}_t^c\right)^{1-\sigma}}{\sum_{c=1}^C \left(\frac{\left(1+t_c^d\right) X_c^d}{E^d}\right) \left(\hat{T}_{ct}^d \hat{\tau}_{ct}^d \hat{\tilde{p}}_t^c\right)^{1-\sigma}}, \tag{C21}$$

where $\hat{E}^d = \sum_{c=1}^C \left(\frac{\left(1+t_c^d\right) X_c^d}{E^d}\right) \hat{T}_{ct}^d \hat{X}_{ct}^d$ is constructed directly from the data. This system can be solved for $\{\hat{\tau}_{ct}^d\}_{c\neq d}$ and $\hat{\tilde{p}}_t^c$. Using this solution, $\hat{r}_t^c = \left(\hat{\tilde{p}}_t^c\right)^{1/\alpha}$ from the pricing equation. Given $\{\hat{r}_t^c\}$ and $\{\hat{V}_{ct}^d\}$, the following two equations for factor demand and supply are then used to recover $\{\hat{\kappa}_{ct}^d\}_{c\neq d}$, $\{\hat{\tilde{r}}_{ct}^d\}$, and $\{\hat{N}_t^c\}$:

$$\frac{\hat{V}_{ct}^d}{\hat{Y}_t^d} = \left(\frac{\hat{\kappa}_{ct}^d \hat{\tilde{r}}_{ct}^d}{\hat{r}_t^d}\right)^{1-\varrho} \tag{C22}$$

$$\left(\hat{\tilde{r}}_{ct}^d\right)^\theta \left(\sum_k \left(\frac{V_c^k}{\sum_k V_c^k}\right) \left(\hat{\tilde{r}}_{ct}^k\right)^\theta\right)^{(1-\theta)/\theta} \hat{N}_t^c = \hat{V}_{ct}^d \tag{C23}$$

where $\hat{Y}_t^d = \sum_{c=1}^C \left(\frac{V_c^d}{\alpha Y^d}\right) \hat{V}_{ct}^d$ is again computed from data. As a final step, it is straightforward to compute $\hat{\delta}_t^c$, but this is not needed for the counterfactuals we run.