Global Supply Chains and Trade Policy*

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Abstract

How do global supply chain linkages modify countries' incentives to impose import protection? Are these linkages empirically important determinants of trade policy? To address these questions, we introduce supply chain linkages into a workhorse model of tariff setting with political economy. Theory predicts that discretionary final goods tariffs will be decreasing in the domestic content of foreign-produced final goods. Provided foreign political interests are not too strong, final goods tariffs will also be decreasing in the foreign content of domestically-produced final goods. Using theory to guide our empirical strategy, we test these predictions with newly assembled data on bilateral applied tariffs, temporary trade barriers, and value-added contents for 14 major economies over the 1995-2009 period. Our results offer strong support for the predictions of the model and demonstrate that global supply chains already play an important role in shaping trade policy.

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In the modern global economy, final goods are typically produced by combining domestic and foreign inputs via global supply chains.[1] In policy circles, there is widespread interest in these global supply chain linkages, which figure prominently in ongoing discussions among trade policymakers as well as in firm lobbying on trade policy.[2] This focus reflects a tacit expectation that global supply chain linkages alter the conventional calculus of trade protection.

Despite this attention, global supply chains are largely absent in theoretical and empirical analysis of trade policy. One reason for this omission is the sheer diversity of global supply chains: some are sequential in nature, others are are not; some are organized within firms, others at arms length; some are primarily bilateral, others involve many countries; and so on. This variety frustrates policy analysis, since these details make it difficult to obtain general lessons and predictions for policy.

In this paper, we cut through the complexity by adopting a value-added approach to evaluating global supply chain activity. The key insight is that supply chain linkages can be thought of in terms of direct trade in factor services (value-added content) on the production side. That is, we leverage the idea that final goods are "made in the world," in effect by combining domestic and foreign primary factors.[3] Embedding this production structure into a workhorse model of trade policy with political economy, we characterize how government objectives over final goods tariffs depend on the nationality of the value-added content embodied in home and foreign final goods. This approach reduces a complex trade policy problem to a general, tractable, intuitive one. In turn, it facilitates empirical analysis.

The theory leads to two main predictions. First, it predicts that discretionary final goods tariffs will be decreasing in the domestic content of foreign-produced final goods. Second, tariffs will be decreasing in the foreign content of domestically-produced final goods, provided foreign political interests are not too strong. Using newly assembled data on bilateral applied tariffs, temporary trade barriers (TTBs), and value-added contents, we test these predictions for 14 major economies over the 1995-2009 period. We find strong support for the empirical predictions of the model: by erasing the distinction between final goods made at home versus those made abroad, global supply chains matter for trade policy.

[1] This theme is reflected in work on vertical specialization, offshoring, multinational production, and global sourcing. Among others, see Feenstra and Hanson (1999), Yi (2003, 2010), Grossman and Rossi-Hansberg (2008), Costinot and Vogel (2013), Antràs, Fort and Tintelnot (2014), and Antràs (2016).

[2] On the role of supply chains in policy discussions, see the WTO's Made in the World Initiative and the 2014 World Trade Report [WTO (2014)]. See also Baldwin (2012) and Hoekman (2014). On lobbying activity, see lobbying materials by the TPP Apparel Coalition on the Trans-Pacific Partnership for example. See also press reports on disputes between Nike versus New Balance on United States import tariffs.

[3] Our approach is conceptually related to task trade approach of Grossman and Rossi-Hansberg (2008), in that we abstract from trade in physical inputs at intermediate stages of processing. Adao, Costinot and Donaldson (2015) also advocate for models of factor exchange.

Our framework and results contribute to both the theoretical and empirical trade policy literature. The first contribution is to extend the canonical theory of trade policy to include cross-border supply chain linkages. To highlight the essential mechanics, we note that the use of foreign value added in production drives a wedge between national income and the value of final goods produced in each country: some revenue from domestic final goods production ultimately accrues to foreigners, while some foreign final goods revenue is paid to home residents. This re-conceptualization of the production process changes the mapping from prices to income, and hence welfare, relative to standard models. As a result, global supply chains alter government incentives to apply import protection.

This general framework captures the most important features of global supply chain activity, while remaining agnostic about particular details of supply chain relationships. The payoff to this approach is that we can proceed without taking a stand on whether supply chains are sequential ("snakes") or roundabout ("spiders") [Baldwin and Venables (2013)], whether input prices are determined by bargaining or market clearing [Antràs and Staiger (2012)], or whether supply chains are organized inside versus outside the firm [Antràs and Chor (2013)]. This is a major advantage, since global supply chains (GSCs) are surely heterogeneous in these (difficult to quantify) dimensions. The mechanism we study requires only that the elasticity of price pass-through from final goods prices to factor prices is (weakly) positive.[4] This reduced-form price mapping holds in many models, so the mechanism we emphasize has wide applicability.[5]

This generality is important because it allows us to derive crisp predictions for optimal bilateral trade policy from the model, which then can be taken to data. Embedding the supply chain mechanism in a many-country, many-good framework with political economy motives, we first characterize unilaterally-optimal bilateral tariffs for final goods. In this analysis, we take into account key institutional features of the multilateral trading system that constrain bilateral policy discretion. We explicitly consider the implications of the GATT most-favored-nation (MFN) rule,[6] We also describe how bilateral tariffs may differ

[4]In the event that the pass-through elasticity is zero, then value-added content is not relevant setting final goods tariffs. Therefore, this possibility is nested inside our empirical framework, in that we would find null results if the elasticity is zero in reality.

[5]While our model features a terms-of-trade mechanism, in which tariffs influence final goods prices, the basic insights are portable to alternative environments. For example, the reduced form mapping from tariffs to factor prices will also operate in the recent class of models that feature extensive margin adjustments and de-location effects in addition to (or instead of) conventional terms-of-trade effects.

[6]While governments have discretion to offer preferential tariffs bilaterally via various trade preference programs (under the GATT's Article XXIV or Enabling Clause), the MFN rule caps bilateral tariffs for many trading partners at levels below the unilaterally optimal tariff. The implication is that we can observe bilateral optimal tariffs up to, but not above, the MFN threshold in the data. We use non-linear methods to address this partial non-observability, or censoring, problem in the estimation.

when they are set via regional (or bilateral) trade agreements (RTAs) versus other unilateral preference programs. This framework for bilateral trade policy analysis is new and marks an additional theoretical contribution of our work.

Starting with unilateral policy, our model demonstrates that the optimal final goods tariff deviates from the standard "inverse export supply elasticity rule" for three reasons. First, domestic content embodied in foreign final goods dampens a country's incentive to manipulate its terms of trade. Put simply, tariffs push down the prices that foreign producers receive, which hurts upstream domestic producers who supply value added to foreign producers. Thus, all else equal, a country will set lower tariffs against imports that embody more of its own domestic value-added content.

Through a second channel, foreign content embodied in domestic final goods also reduces the government's incentive to impose tariffs. Intuitively, when import-competing sectors use foreign inputs, some protectionist rents from higher tariffs accrue to foreign upstream suppliers. This mechanism also reduces the government's incentive to apply import protection. Importantly, this effect of foreign value-added content on tariffs arises even if the government has no ability (or motive) to manipulate its terms of trade; this channel thus constitutes a distinct international externality, which we refer to as the domestic-price externality.

Political economy (distributional) concerns are a third source of deviations from the inverse elasticity rule.[7] If the government affords additional political weight to domestic suppliers of value added embodied in foreign final goods, the tariff liberalizing effect via the first channel will be stronger. Conversely, if the government affords political weight to suppliers of foreign value added embodied in domestic goods, these political concerns may weaken (or even overturn) the second channel.

Recognizing that some tariff preferences are set via regional trade agreements, we then consider whether and how cooperation in bilateral tariff setting would alter these results. If cooperative agreements neutralize terms-of-trade externalities, as posited by Grossman and Helpman (1995*b*) and Bagwell and Staiger (1999), then tariffs inside RTAs may respond differently to value-added content than those set outside RTAs. Specifically, if RTAs neutralize bilateral terms-of-trade motives over final goods, then tariffs set via RTAs may be insensitive to the amount of domestic value added embodied in foreign goods. In contrast, theory suggests that foreign value added in domestic production would continue to influence tariff setting, even under RTAs.[8]

[7]In addition to the new political economy results concerning value added content emphasized above, standard political economy mechanisms are also active in the model. Specifically, politically optimal tariffs rise if the government favors domestic producers of final goods. Though familiar, this last point is important for taking the theory to data [Goldberg and Maggi (1999), Gawande and Bandyopadhyay (2000)].

[8]There are two reasons. First, foreign value added shapes tariffs via a domestic-price externality rather

We combine data on bilateral import protection and value-added contents to test the main predictions of the theory. Our analysis focuses on dimensions of policy over which governments have scope to implement discretionary levels of protection.[9] We first examine bilateral applied tariffs, where countries offer preferential tariffs to selected partners. We then examine the use of temporary trade barriers (antidumping, safeguards, and countervailing duties) in a separate, complementary set of exercises. Throughout, we measure value-added contents using input-output methods and data from the World Input-Output Database.

Theory motivates the empirical specifications we adopt and our choice of controls. In a first specification, we focus on identifying the role of domestic value added in foreign production, using fixed effects to control for export supply elasticities, political economy, and foreign value-added effects. We then turn to a second theory-based specification to identify the role of foreign value added in domestic production.

Summarizing our results, we first find that higher domestic value added in foreign final goods results in lower applied bilateral tariffs. This result holds across alternative specifications that control for confounding factors using both observable proxies and fixed effects. Further, this liberalizing effect of domestic value added holds for tariffs set outside RTAs, but not for those set within RTAs. The estimated influence of domestic value added on tariffs becomes stronger when we instrument for domestic value-added content and correct for censoring of applied bilateral tariffs induced by the MFN rule.

Second, we find that higher foreign value added in domestic final goods results in lower applied bilateral tariffs. This effect again strengthens when we correct for censoring and holds most strongly inside RTAs.

Finally, we show that bilateral TTB coverage ratios respond to value-added content in much the same way as bilateral applied tariffs. These results both corroborate our findings for tariffs and extend our analysis to include these increasingly important discretionary trade policy instruments. Furthermore, we find the role of domestic value added in foreign production to be strongest for TTB-use against China, where antidumping and other TTBs were most actively deployed during the 1995-2009 period.

In all of our theoretical and empirical analysis, we focus on trade policy over final goods, setting aside questions concerning optimal input tariffs. We pause here to briefly explain this choice of emphasis. As a launching point, global supply chains blur the distinction

than through the terms of trade. Existing theory is silent on whether RTAs would eliminate all potential externalities among signatories, or just those that operate through the terms of trade. Second, the foreign value added effect is multilateral (unlike the bilateral effect of domestic value added), and so it is not clear how, if at all, tariffs under RTAs would respond.

[9] Our study is thus in the tradition of earlier work examining unconstrained dimensions of policy, including Trefler (1993), Goldberg and Maggi (1999), Gawande and Krishna (2003), Broda, Limão and Weinstein (2008), Bown and Crowley (2013), and Blanchard and Matschke (2015), among others.

between what is "made at home" versus "made abroad." Translating this idea into trade policy analysis is most straightforward conceptually for final goods, both because value-added content is readily measurable and because we can employ a factor exchange representation of production in the analysis.[10] In addition, as a practical matter, multilateral applied input tariffs are very low, both in absolute terms and relative to final goods tariffs [Bown and Crowley (forthcoming)]. Because our analysis presumes that governments have scope for bilateral discretion in setting trade policy, protection of final goods is the natural empirical context in which to test the theory.

Our study is related to several recent contributions to the theory of trade policy. Our framework and findings complement Antràs and Staiger (2012), who analyze how bilateral bargaining among supply chain partners alters the mapping from tariffs to prices, and therefore optimal trade policy for both final goods and inputs. In contrast to their approach, we are agnostic about the nature of price determination within global supply chains; our results obtain even if prices are determined by market clearing conditions, as in conventional models. Most directly, our theory builds on Blanchard (2007, 2010), who shows that foreign direct investment and international ownership also alter the mapping from prices to income, and thus optimal tariffs. Though similar in spirit, the mechanics in this paper are distinct: the theory here links observable input trade patterns to bilateral tariffs, separate from ownership concerns. Further, the theory we develop here is explicitly designed to be taken to data, which informs the novel way we model trade and price elasticities, political economy, and heterogeneity across different sectors and trading partners.

Turning to the empirical literature on trade policy, our results on bilateral tariffs echo Blanchard and Matschke (2015), who show that the United States is more likely to offer preferential market access to destinations that host US multinational affiliates. In contrast to this work on multinational ownership, we emphasize again that our focus is on input trade, and our application extends to tariffs and TTBs for 14 major economies. This shift in emphasis is important, not least because scale of cross-border input linkages is large relative to multinational production for most countries and sectors.[11] More broadly, our evidence linking the domestic value-added content in foreign production to preferential tariffs

[10] From a measurement perspective, there is a unique decomposition of the value of final goods into home versus foreign value added. The value of intermediate inputs cannot be similarly decomposed, because by definition these goods are at an intermediate stage of processing. In terms of theory, one needs to take a stand on many structural details regarding input trade (e.g., sequential vs. roundabout, market clearing vs. bargaining) to make policy statements. This makes such statements highly conditional and thus precludes the type of general empirical analysis we conduct here.

[11] 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. In turn, imported final goods contain substantial domestic value added, as exported intermediate inputs return home embodied in foreign-made final goods.

and TTBs fits into an important literature documenting the determinants of trade policy, including the role of the terms-of-trade [Broda, Limão and Weinstein (2008), Bagwell and Staiger (2011), Ludema and Mayda (2013), Bown and Crowley (2013)]. We are the first (to our knowledge) both to demonstrate both the relevance of terms-of-trade concerns for *bilateral* tariff policy, and to document that tariffs set via RTAs behave in a manner consistent with the neutralization of terms-of-trade motives.[12]

Finally, this paper contributes to a recent literature that applies input-output methods to measure the value-added content of trade [Johnson and Noguera (2012), Koopman, Wang and Wei (2014), Los, Timmer and de Vries (2015)]. Drawing on this work, we examine the implications of value-added contents for a particular set of economic policies.

The paper proceeds as follows. Section 1 presents the theoretical framework. Section 2 outlines our empirical strategy for taking the theory to data. Section 3 describes the data. Sections 4 and 5 include the empirical results, and Section 6 concludes.

1 Theoretical Framework

This section develops a many-country, many-good, political-economy model in which value-added content influences the structure of bilateral tariffs on final goods. We open with a general discussion of our modeling choices, then proceed to the formal characterization of optimal tariffs.

1.1 Modeling Bilateral Trade Policy

Building on existing trade policy models, we design our theoretical framework to respect the institutional context in which bilateral trade policy is set. First, we dedicate special attention to two institutional issues that figure prominently in our empirical investigation: the most-favored-nation (MFN) rule and the potential drivers of tariff variation under bilateral or regional free trade deals.

The MFN Rule The most-favored-nation rule dictates that WTO members may not discriminate across their WTO-member trading partners, but for defined exceptions to this rule. Further, MFN-exceptions defined under the GATT's Article XXIV and Enabling Clauses allow downward deviations from MFN only – i.e., countries may offer tariff preferences, but

[12]On the first point, our work complements Bown and Crowley (2013), who document the importance of terms-of-trade influences in US application of bilateral antidumping and safeguard measures.

they may not impose higher-than-MFN discriminatory tariffs. As a result, MFN tariff rates serve as an upper bound on applied bilateral tariffs.[13]

In our model, we analyze how discriminatory bilateral tariffs respond to value-added content, given this MFN constraint. In doing so, we take MFN tariffs as given. Notably, this assumption follows Grossman and Helpman (1995*a*), who also take MFN tariffs as given when analyzing politically-optimal bilateral trade agreements.[14]

More pertinent to our empirical application, there are two important reasons to focus on bilateral deviations from MFN, rather than MFN tariffs themselves. First, current MFN tariffs were set primarily under the Uruguay Round, which was completed in 1994.[15] Not only does this predate our sample period, but the MFN negotiations also largely predated the post-1990 rise in global supply chain activity. In contrast, bilateral tariff preferences are an active area of trade policy during the 1995-2009 period, and thus a more fertile ground for empirical exploration. Second, the empirical framework that we develop exploits variation in tariff preferences across trade partners within a given importer and industry. Thus, we effectively difference away MFN tariffs (and their multilateral determinants) in all of our empirical specifications.

RTAs While the the majority of observed bilateral preferences in our data are unilateral in nature, some are the result free trade agreements or customs unions, permitted under GATT Article XXIV. Because these agreements are ostensibly the result of comprehensive negotiations between partner countries, negotiations may (at least in part) neutralize bilateral terms-of-trade externalities, per existing theory [Grossman and Helpman (1995*b*)]. Accordingly, we take care to analyze tariff preferences under RTAs separately from unilateral preferences. We first derive optimal bilateral tariffs under the assumption that preferences are set unilaterally. We then characterize the potential for cooperation between RTA members to change relationship between value added and preferential tariffs within RTAs.

[13] Temporary trade barriers (anti-dumping, countervailing duties, and safeguards) are the key exception in which discretionary trade policy consists of *upward* deviations from MFN tariffs. We explore these alternative instruments of trade policy in Section 5.

[14] To justify this assumption, Grossman and Helpman (1995*a*) appeal to GATT Article XXIV, which prohibits countries that adopt bilateral agreements from raising their external (MFN) tariffs. Further consistent with this assumption, existing theoretical and empirical work finds that tariff preferences have an ambiguous impact on MFN tariffs. See Bagwell and Staiger (1997), McLaren (2002), Saggi (2009) for theoretical analysis. On the empirics, Limão (2006) finds that tariff preferences make subsequent MFN liberalization less likely, while Estevadeordal, Freund and Ornelas (2008) find the opposite.

[15] This is true for industrialized countries. As a legacy of the Uruguay round, MFN tariffs for these countries sometimes fall during our sample period due to extended phase-in schedules. Although MFN tariffs for several emerging markets were lowered during our sample period, either unilaterally or in conjunction with joining the WTO, our empirical strategy ensures that these MFN tariff changes do not drive the results.

Additional Model Background To facilitate presentation of the main ideas, we make a number of additional technical assumptions.

We focus on a tractable partial equilibrium setting with a numéraire sector and quasi-linear preferences. This set up isolates the direct determinants of trade policy, separate from potential general equilibrium contaminants.[16]

To simplify the exposition, we adopt a specific factors structure for primary inputs. The innovation is that we extend the specific factors logic across borders: we assume that factors are specific to the sector and destination country in which they are used to produce final goods. While this assumption is helpful for tractability and developing intuition, it is not essential. In Appendix A, we re-derive the core results in a generalized environment with imperfectly substitutable factors in production. Imperfect substitution is sufficient to generate the mapping from final goods prices to factor prices on which the theory rests.

In the background, our model also implicitly takes input tariffs as given.[17] The logic for doing is as follows. Input tariffs alter value-added content by changing input prices and/or sourcing decisions. Therefore, input tariffs influence final goods tariffs via value-added contents. Given value-added contents, however, input tariffs have no additional (first-order) impact on final goods tariffs.[18] As such, we do not address them directly.

Finally, although the theory focuses on bilateral tariffs, import protection takes other forms, most notably the discretionary use of upward deviations from MFN tariffs via anti-dumping duties and related temporary trade barriers. We defer discussion about how we extend our arguments to the TTB environment until Section 5.

1.2 Model Set-up

Consider a multi-country, multi-good setting in which every country produces and trades potentially many final goods. The set of countries is given by $\mathcal{C} = \{1, ..., C\}$, where C may

[16]This approach follows Grossman and Helpman (1994) (1995), Broda, Limão and Weinstein (2008), Ludema and Mayda (2013) and many others.

[17]We also set aside questions about how value-added trade might affect optimal export policy, in keeping with both the existing literature and institutional limits. GATT rules prohibit export subsidies, and export taxes are seldom used and, in the US, even unconstitutional.

[18]In our model, the only link between input tariffs and final goods tariffs works through tariff revenue, whereby changes in final goods tariffs may induce changes in the value of imported inputs and thus tariff revenue. Due to our specific-factors assumption, this effect obtains only for ad-valorem tariffs. Further, this channel is shut down when input tariffs are set to zero. In reality, input tariffs are sufficiently low that we abstract from them completely. For example, Bown and Crowley (forthcoming) find that in high income and emerging countries, MFN applied tariffs are 70-75 percent higher for final goods than for intermediate inputs (and more than 90 percent higher in developing countries) [p.15]. Finally, if import tariffs take the form of a tax on foreign content, then they can be readily incorporated into the framework. In that case, they appear in coefficients attached to value-added content in the optimal tariff, without changing comparative static results.

be large. There are $S+1$ final goods, where the numéraire final good is indexed by 0, and all other (non-numéraire) goods are indexed by the set $\mathcal{S} = \{1, ..., S\}$. Final goods prices in each country are denoted by p_s^c, where c designates the location and s the final goods sector. The numéraire is freely traded, so that $p_0^c = 1$ for all countries $c \in \mathcal{C}$. We use $\vec{p}^c = (p_1^c, ..., p_S^c)$ to denote the vector of (non-numéraire) final goods prices in country c, $\vec{p}_s = (p_s^1, ..., p_s^C)$ to denote the vector of sector s prices in each country, and $\vec{p} = (\vec{p}^1, ..., \vec{p}^C)$ to represent the complete $(1 \times SC)$ vector of final goods prices in every country world-wide.[19]

Each country is populated by a continuum of identical workers with mass normalized to one. Consumers' preferences are identical and quasi-linear, given by the aggregate utility function:

$$U^c = d_0^c + \sum_{s \in \mathcal{S}} u_s(d_s^c) \qquad \forall c \in \mathcal{C}, \tag{1}$$

where d_s^c represents consumption of final goods in sector s in country c and sub-utility over the non-numéraire goods is differentiable and strictly concave. Consumption is chosen to maximize utility subject to the budget constraint, $d_0^c + \sum_s p_s^c d_s^c \leq I^c$, where I^c is national (aggregate) income in country c, measured in the numéraire.

Production Each country is endowed with two types of factors. The first is a homogeneous factor, which is perfectly mobile across sectors within each country but cannot move across countries. The numéraire good is produced under constant returns to scale using the homogeneous factor (e.g., undifferentiated labor), which normalizes the wage to one in all countries. The second is a specific factor, which we refer to as "value-added inputs."[20] With global supply chains, each country's value-added inputs may be used in production of final goods both at home and abroad. Further, we assume these value-added inputs are specific to the destination country and sector in which they are used to produce final goods.

Final goods in non-numéraire sector s in country c are produced using the homogeneous factor, domestic value-added inputs, and foreign value-added inputs:

$$q_s^c = f_s^c(l_s^c, \nu_{sc}^c, \vec{\nu}_{s*}^c) \quad \forall s \in \mathcal{S}, c \in \mathcal{C}, \tag{2}$$

where q_s^c is quantity of final goods produced, l_s^c is the quantity of homogeneous factor used,

[19] It often proves useful to partition price vectors into domestic and foreign components [Bagwell and Staiger (1999)]. From the perspective of a given home country i, let $\vec{p} \equiv (\vec{p}^i, \vec{p}^*)$, where $\vec{p}^*$ is the $(1 \times S(C-1))$ vector of prices in every country other than i. Likewise, let $\vec{p}_s \equiv (p_s^i, \vec{p}_s^*)$ where $\vec{p}_s^*$ is the $(1 \times (C-1))$ vector of prices on s in every country other than i.

[20] These value-added inputs are simply bundles of specific primary factors. One could replace the term value-added inputs everywhere with "specific capital" or "specific human capital" (or any other composite of specific primary factors) and all the results go through. We prefer the value-added nomenclature because it is tied to what we measure in the data.

ν^c_{sc} is the quantity of the home (country c) value-added input used, and $\vec{\nu}^c_{s*}$ is the $(1 \times (C - 1))$ vector of foreign value-added inputs used by sector s in country c.[21] As a notational convention, superscripts denote the country-location of production, and subscripts denote the production sector and country-origin of value-added inputs.

As is standard, the specific value-added inputs capture all residual profit (quasi-rents) from production, so the prices paid to the specific value-added inputs vary endogenously with final goods prices. The quasi-rent associated with production by sector s in country i (π^i_s) is given by:

$$\pi^i_s(p^i_s) = p^i_s q^i_s(p^i_s) - w l^i_s(p^i_s) = \sum_{c \in \mathcal{C}} r^i_{sc} \nu^i_{sc}, \tag{3}$$

where r^i_{sc} denotes price of value-added inputs from each country $c \in \mathcal{C}$ used in production of s in country i. Value-added input prices r^i_{sc} depend on final goods output prices and the vector of value-added inputs in production: $r^i_{sc} \equiv r^i_{sc}(p^i_s; \vec{\nu}^i_s)\ \forall i, j, s$.

This view of the production process and the role of global supply chains is intentionally reduced form and captures two essential features. First, output is produced using both home and foreign production factors when supply chains span borders.[22] Second, global supply chain activities are characterized by high degrees of input specificity and lock-in between buyers and suppliers, as emphasized by Antràs and Staiger (2012), which manifests itself in our model as factor specificity.[23]

The model captures these ideas without taking a stand on the underlying production structure by which factors are transformed into final goods via global supply chains, and thus without specifying the exact division of quasi-rents across the different value added components. We assume only that the mapping from final goods prices to the vector of quasi-rents is well-defined and can be represented by elasticity terms of the form ε^{ri}_{sc}, which describes how changes in the price of a final good are passed through to value-added inputs.[24]

[21] It proves helpful to partition the $(1 \times C)$ vector of value-added inputs, $\vec{\nu}^c_c$, into local value-added inputs, ν^c_{sc}, and the $(1 \times (C - 1))$ vector of foreign value-added inputs, denoted by an asterisk: $\vec{\nu}^c_s \equiv (\nu^c_{sc}, \vec{\nu}^c_{s*})$.

[22] This technology abstracts from supply side details concerning how value-added input trade takes place. A simple interpretation is that intermediate inputs are produced at home and shipped abroad to be assembled into final goods. More complicated supply chains spread over multiple countries are also possible. Both representations map to Equation (2) as a reduced form.

[23] In Appendix A, we extend the model to relax the specific factors assumption, replacing it with assumptions that imply value-added inputs are imperfectly substitutable in production. We show this preserves both the key mechanisms and empirical predictions of the framework.

[24] Formally, let ε^{ri}_{sc} denote the elasticity of the return to country c's value added embodied in sector s production in country i with respect to changes in the local price of final goods in sector s in country i. These elasticity terms will depend on various (unmodeled) supply side primitives (e.g., production structure, market frictions, market power, etc.).

National Income National income equals the sum of tariff revenue and payments to the homogeneous factor and value-added inputs:

$$I^i = R(\vec{p}, I^i; \vec{\nu}) + 1 + \sum_{s\in\mathcal{S}} r^i_{si}\nu^i_{si} + \sum_{s\in\mathcal{S}} \sum_{c\neq i\in\mathcal{C}} r^c_{si}\nu^c_{si}, \tag{4}$$

where tariff revenue is $R(\vec{p}, I^i; \vec{\nu}) \equiv \sum_{s\in\mathcal{S}} \sum_{c\neq i\in\mathcal{C}} (p^i_s - p^c_s) M^i_{sc}(\vec{p}, I^i; \vec{\nu})$, M^i_{sc} is country i's imports of good s from country c, and labor income of the homogeneous factor is 1 due to normalization. Using (3), we can rewrite (4) as:

$$I^i = 1 + \vec{p^i} \cdot \vec{q^i}(\vec{p^i}, \vec{\nu^i}) + R(\vec{p}, I^i; \vec{\nu}) - \underbrace{\sum_{s\in\mathcal{S}} \sum_{c\neq i\in\mathcal{C}} r^i_{sc}\nu^i_{sc}}_{\equiv FVA^i(\vec{p^i})} + \underbrace{\sum_{s\in\mathcal{S}} \sum_{c\neq i\in\mathcal{C}} r^c_{si}\nu^c_{si}}_{\equiv DVA_i(\vec{p}^*)}. \tag{5}$$

The first three components of Equation (5) mirror traditional models, in which national income equals final goods output plus tariff revenue. There are two adjustments to this standard definition of income due to global supply chain linkages. First, some of the revenue from domestic final goods production is paid to foreign factors of production (foreign value-added inputs). Henceforth, we refer to these payments to foreign factors as FVA, or *foreign value added in domestic final goods*. Second, the home country earns income by supplying home value-added inputs to foreigners. We refer to these payments as DVA, or *domestic value added in foreign final goods*. Foreshadowing the key mechanism below, note that DVA and FVA depend on final goods prices, via value-added input prices. Because tariffs influence these prices, trade policy affects income in a non-standard way in our model.

Political Economy We assume the government's objective function is given by the sum of national income, consumer surplus, and the weighted sum of quasi-rents in production:

$$G^i = I^i + \zeta(\vec{p^i}) + \sum_s [\delta^i_s \pi^i_s(p^i_s) + \delta^i_{s*} FVA^i_s(p^i_s) + \delta^*_{si} DVA_{si}(\vec{p}^*_s)], \tag{6}$$

where $\zeta(\vec{p^i}) \equiv \sum_s [u_s(d_s) - p^i_s d_s]$ is consumer surplus and $\{\delta^i_s, \delta^i_{s*}, \delta^*_{si}\}$ are political economy weights (relative to aggregate welfare) attached to various sources of rents.

This objective function augments standard political economy assumptions to recognize the potential political influence of foreign and domestic supply chain interests. The first two terms measure the indirect utility of the representative consumer (aggregate welfare). The remaining terms capture political economy influences: δ^i_s is the weight that the government puts on total rents from domestic final goods production, δ^i_{s*} is the weight placed on rents from domestic production that accrue to foreign value-added inputs (FVA^i_s), and δ^*_{si} is the weight placed on rents accruing to domestic value-added inputs used in foreign final goods production (DVA_{si}). We do not impose a priori restrictions on the weights, but standard arguments would imply positive values for politically active constituencies.[25]

1.3 Optimal Bilateral Tariffs

We are now ready to characterize unilaterally optimal bilateral tariffs. Given the partial equilibrium setting, we can characterize optimal bilateral tariffs one good at a time, as each is independent of the other goods' prices or tariffs.

Country i's optimal tariff on final goods in sector x against a given trading partner $j \in \mathcal{C}$ maximizes Equation (6) subject to two constraints. The first is a standard no arbitrage condition: $p^i_x = \tau^i_{xj} p^j_x$, where $\tau \equiv (1 + t^i_{xj})$ and t^i_{xj} is the ad valorem tariff. The second is the MFN rule, as discussed earlier. Letting $t^{i,\text{MFN}}_x$ denote the MFN tariff, then the MFN rule implies that $t^{i,\text{applied}}_{xj} \leq t^{i,\text{MFN}}_x$, where $t^{i,\text{applied}}_{xj}$ is the bilateral applied tariff. Given the allocation of specific value-added inputs, every other country's tariff schedules, and its own MFN tariffs, country i's unilaterally optimal tariff on imported good x from country j is given by:

$$\tau^i_{xj} = \arg\max \; G^i \quad \text{s.t.} \quad p^i_x = \tau^i_{xj} p^j_x \text{ and } \tau^i_{xj} \leq \tau^{i,MFN}_x. \tag{7}$$

If the optimal tariff is unconstrained, then it solves the following first order condition:

$$G^i_{\tau^i_{xj}} = \frac{dM^i_x}{d\tau^i_{xj}} t^i_{xj} p^j_x - M^i_{xj} \frac{dp^j_x}{d\tau^i_{xj}} + \delta^i_x q^i_x \frac{dp^i_x}{d\tau^i_{xj}} + \Omega^{Ri}_{xj} - (1-\delta^i_{x*}) \frac{dFVA^i_x}{d\tau^i_{xj}} + (1+\delta^*_{xi}) \frac{dDVA_{xi}}{d\tau^i_{xj}} = 0. \tag{8}$$

The first two terms of this expression capture the standard terms-of-trade motive, and the third term represents the (familiar) effect of domestic protectionist political pressure.[26] The term $\Omega^{Ri}_{xj} \equiv \sum_{c \neq i,j} \frac{dR^i_{xc}}{d\tau^i_{xj}}$ captures the potential for trade diversion to change country

[25] These weights reflect a range political economy forces. The restriction $\delta^i_s = \delta^i_{s*} = \delta^*_{si} = 0$ yields a national welfare maximizing government. Standard protection-for-sale lobbying would imply $\delta^i_x > 0$ for a politically active industry [Grossman and Helpman (1994)]. Similarly, δ^*_{xi} would be positive if domestic value-added input suppliers advocate for better market access on behalf of their foreign downstream buyers. To the extent that the government responds to the interests of foreign value-added input suppliers, δ^i_{s*} would also be positive. For instance, foreigners could lobby directly over trade policy [Gawande, Krishna and Robbins (2006)]. Alternatively, foreign value-added inputs suppliers could be represented in domestic politics by their downstream buyers, as in tariff jumping foreign investors that earn political goodwill [Bhagwati et al. (1987)] and advocate on behalf of their upstream affiliates located abroad. Finally, we implicitly assume that the home government affords zero consideration to foreign value-added inputs in foreign production, though this assumption could also easily be relaxed.

[26] Tariffs influence final goods prices in the usual way: an increase in country i's bilateral tariff on good x against a trading partner country j, τ^i_{xj}, causes the price of x to rise in the imposing country (i), and fall in trading partner j. That is, we rule out the Metzler and Lerner paradoxes such that: $\frac{dp^i_x}{d\tau^i_{xj}} \geq 0 \geq \frac{dp^j_x}{d\tau^i_{xj}}$.

i's tariff revenue from trade with countries other than j.[27] The last two terms capture the politically-weighted influence of trade in value-added inputs on the optimal tariff.

Consider first the role of foreign value added embodied in domestic final goods (FVA). The bilateral tariff raises the local final goods price (p_x^i), which in turn increases the returns to foreign value-added inputs embodied in domestic production ($r_{xc}^i(p_x^i)$). We decompose this effect as follows:

$$\frac{dFVA_x^i}{d\tau_{xj}^i} = \sum_{c \neq i} \left[\frac{r_{xc}^i \nu_{xc}^i}{p_x^i} \underbrace{\left(\frac{dr_{xc}^i}{dp_x^i} \frac{p_x^i}{r_{xc}^i} \right)}_{\equiv \varepsilon_{xc}^{ri} \geq 0} \right] \frac{dp_x^i}{d\tau_{xj}^i} = \varepsilon_{x*}^{ri} \sum_{c \neq i} \frac{r_{xc}^i \nu_{xc}^i}{p_x^i} \frac{dp_x^i}{d\tau_{xj}^i} = \varepsilon_{x*}^{ri} \frac{FVA_x^i}{p_x^i} \frac{dp_x^i}{d\tau_{xj}^i}. \tag{9}$$

The term $\varepsilon_{xc}^{ri} \equiv \frac{dr_{xc}^i}{dp_x^i} \frac{p_x^i}{r_{xc}^i}$ is the elasticity of foreign value-added input prices with respect to local final goods prices. We assume this elasticity is positive: a higher price on a final good implies higher returns to the value-added 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 $\varepsilon_{xc}^{ri} = \varepsilon_{x*}^{ri}\ \forall c \neq i \in \mathcal{C}$ (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 value-added inputs. We decompose the direct and indirect price effects of the tariff as follows:

$$\frac{dDVA_{xi}}{d\tau_{xj}^i} = \frac{r_{xi}^j \nu_{xi}^j}{p_x^j} \underbrace{\left(\frac{dr_{xi}^j}{dp_x^j} \frac{p_x^j}{r_{xi}^j} \right)}_{\equiv \varepsilon_{xi}^{rj} \geq 0} \frac{dp_x^j}{d\tau_{xj}^i} + \Omega_{xj}^{DVAi} = \varepsilon_{xi}^{rj} \frac{DVA_{xi}^j}{p_x^j} \frac{dp_x^j}{d\tau_{xj}^i} + \Omega_{xj}^{DVAi}. \tag{10}$$

The direct price effect captures how τ_{xj}^i impacts the price of i's value-added used by the country (j) on which the tariff is imposed. The indirect price effect encompasses how the tariff impacts the price of i's value-added inputs used in third countries. In what follows, we focus on the direct effects and collect the indirect effects in Ω_{xj}^{DVAi}.[28] The strength of this direct effect is governed by the elasticity $\varepsilon_{xi}^{rj} \geq 0$. As above, we assume this elasticity is positive: a higher price of good x in country j implies a higher price for country i's value-added inputs used in production of that good.

[27] The price of x in other countries may respond to the tariff as a result of trade diversion. In general, the direction of third-country price movements are ambiguous absent additional modeling assumptions. Theoretical work has used various techniques to restrict the external price effects of bilateral tariffs, usually by adopting a 'competing exporters' framework [Bagwell and Staiger (1997)] or a small country assumption [e.g. Grossman and Helpman (1995*a*)].

[28] For completeness, $\Omega_{xj}^{DVAi} \equiv \frac{dDVA_{xi}^{-j}}{d\tau_{xj}^i} = \sum_{c \neq i,j} \frac{dDVA_{xi}^c}{dp_x^c} \frac{dp_x^c}{d\tau_{xj}^i} = \sum_{c \neq i,j} \varepsilon_{xi}^{rc} \frac{DVA_{xi}^c}{p_x^c} \frac{dp_x^c}{d\tau_{xj}^i}$. The consequences of any third-country effects are ambiguous and plausibly inconsequential (e.g. when trade diversion is minimal). See Freund and Ornelas (2010) for a comprehensive review of the literature.

Substituting Equations (9) and (10) into Equation (8), we solve for the (unconstrained) optimal bilateral tariff:

$$t_{xj}^{i}=\frac{1}{\epsilon_{xj}^{i}}\left(1+\frac{\delta_x^i q_x^i}{|\lambda_{xj}^{i}|M_{xj}^{i}}-(1+\delta_{xi}^{*})\varepsilon_{xi}^{rj}\frac{DVA_{xi}^{j}}{p_x^j M_{xj}^{i}}-\frac{(1-\delta_{x*}^{i})\varepsilon_{x*}^{ri}}{|\lambda_{xj}^{i}|}\frac{FVA_x^i}{p_x^i M_{xj}^{i}}-\tilde{\Omega}_{xj}^{i}\right), \tag{11}$$

where $\lambda_{xj}^{i}\equiv\frac{dp_x^j}{d\tau}/\frac{dp_x^i}{d\tau}<0$, $\epsilon_{xj}^{i}\equiv\frac{dE_{xi}^{j}}{dp_x^j}\frac{p_x^j}{E_{xi}^{i}}>0$ represents the bilateral, sector-specific export supply elasticity, and $\tilde{\Omega}_{xj}^{i}\equiv\frac{\Omega_{xj}^{Ri}+\Omega_{xj}^{DVAi}}{(dp_x^j/d\tau_{xj}^{i})M_{xj}^{i}}$ captures any potential third-country effects of trade diversion.[29] Incorporating the MFN constraint, the *applied* bilateral tariff will be the lesser of the expression in (11) and the MFN tariff:

$$t_{xj}^{i,\text{applied}}=\min\{t_{xj}^{i},t_x^{i,MFN}\}. \tag{12}$$

Discussion Equations (11) and (12) trace out the role of supply chain linkages and political economy in shaping applied bilateral tariffs. There are four key elements in Equation (11).

The first two elements are well-understood. They are the inverse export supply elasticity ($\frac{1}{\epsilon_{xj}^{i}}$) and the inverse import penetration ratio ($\frac{\delta_x^i q_x^i}{|\lambda_{xj}^{i}|M_{xj}^{i}}$). The inverse export supply elasticity captures the familiar terms-of-trade, cost-shifting motive for tariffs [Johnson (1951-1952)]. The inverse import penetration ratio captures the influence of domestic political economy concerns, whereby the government trades off the interests of import-competing domestic producers of good x against social welfare. This standard theoretical result has substantial empirical support [Goldberg and Maggi (1999), Gawande and Bandyopadhyay (2000)].

The third element is new and captures the the role of domestic value added in foreign production: when DVA_{xi}^{j} is high, the government optimally sets a lower bilateral tariff. The reason is that lowering the tariff raises the price of foreign final goods, and some of this price increase is passed back to the home country in the form of higher prices for domestic value-added inputs. This mechanism drives down the optimal tariff even when the domestic government values only national income ($\delta_{xi}^{*}=0$); the effect is reinforced when the government affords additional political consideration ($\delta_{xi}^{*}>0$) to the interests of domestic value-added input suppliers. In effect, a large importing country internalizes some of the terms-of-trade externality when its value added is embodied in foreign final goods.

The fourth element is also new and captures the role of foreign value added in domestic production (FVA_x^i). Foreign value added influences the optimal tariff through a separate

[29] Note that 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 (11) evaluated at the world tariff vector for which every country's tariff reaction curves intersect.

international cost-shifting margin. By reducing its tariffs, the government of country i lowers *domestic* prices. These lower domestic prices benefit domestic consumers at the expense of import-competing final goods producers. But when the import-competing sectors use foreign value-added inputs ($FVA_x^i > 0$), some of these losses can be passed upstream to foreign input suppliers.[30] Thus, the benefits to consumers of lower tariffs are shifted partly onto foreigners. This mechanism constitutes a distinct "domestic-price externality" that will drive down the optimal bilateral tariff, all else equal.

When the government assigns positive political weight to the interests of foreign value-added input suppliers ($\delta_{x*}^i > 0$), this effect is attenuated. The more the government values foreign input suppliers, then the less it will be motivated to lower tariffs at their expense. As long as domestic consumer concerns dominate the interests of foreign value-added suppliers ($\delta_{x*}^i < 1$), bilateral tariffs nonetheless will be decreasing in FVA.[31]

Two final points are worth noting. First, the DVA and FVA terms are both scaled by bilateral imports (M_{xj}^i), just as in the import penetration ratio term. This scaling arises because the political and value-added terms act as counterweights to the standard terms-of-trade motive, the strength of which depends on the level of bilateral imports. The fact that imports induce bilateral variation in the strength of the FVA effect will play a role in the empirics below. Second, the influence of value added in shaping optimal tariffs is governed (in part) by the value-added elasticities, ε_{xi}^{rj} and ε_{x*}^{ri}, which capture the extent to which changes in final goods prices are ultimately passed through to value-added input prices. The strength of these effects will be embedded in coefficient estimates.

1.4 Regional Trade Agreements

Some tariff preferences are granted via bilateral or regional trade agreements (RTAs), under which governments may cooperate to set more efficient tariffs among signatory countries. The existing literature suggests that negotiated tariff setting may mitigate or even eliminate terms-of-trade cost-shifting externalities [Grossman and Helpman (1995*b*), Bagwell and Staiger (1999)]. If true, we would expect bilateral tariffs to respond differently to DVA and

[30]Note that this effect is essentially multilateral, since any change in country i's local price of x is passed on to all foreign suppliers. We imposed a common pass-through elasticity above, which implies that only the multilateral value of foreign value added appears in the optimal tariff expression. Relaxing this assumption, one would replace this multilateral value with an elasticity-weighted average of foreign value added.

[31]We do not rule out the possibility that the government places greater value on the interests of foreign value-added owners than on its domestic consumers ($\delta_{x*}^i > 1$). If true, bilateral tariffs will be increasing with FVA. Our empirical strategy allows for this possibility, in that we estimate the relationship between FVA and tariffs without a priori sign restrictions. Nonetheless, we do not expect to find a positive relationship, given empirical evidence that governments value aggregate social welfare far more than even domestic political interests (e.g., see Goldberg and Maggi (1999) for the United States).

FVA within versus outside of RTAs.

Specifically, if RTAs eliminate terms-of-trade motives for final goods, then we would not expect to see the imprint of DVA on tariff preferences under RTAs. Since the effect of DVA works entirely through foreign local prices – and thus the bilateral terms of trade – an agreement that neutralizes terms-of-trade effects must also neutralize any (offsetting) influence of DVA. We therefore expect that the influence of DVA on observed tariffs may be weaker, or possibly non-existent, within RTAs – a prediction that we can examine in the data. In light of this prediction, we also take care to document that DVA influences tariff preferences in a restricted sample that excludes RTAs.

The anticipated effect of FVA under an RTA is less clear, since the effect of FVA on the unilaterally optimal tariff works through a *domestic* (local) price externality. As far as we know, neither the theoretical nor empirical trade literature speaks to the potential for cooperative agreements to mitigate behind-the-border externalities.[32] If RTAs eliminate *all* cross-border externalities between countries then we might also expect the effect of FVA to disappear under cooperative agreements. Otherwise, we would expect the FVA effect to remain. Moreover, because the FVA effect reflects a *multilateral* externality, it is not clear how, if at all, a bilateral or regional trade agreement would mitigate the role of FVA. Ultimately, we leave this open empirical question to be answered by data. As with DVA, we anticipate the potential for heterogeneous coefficients across RTA and non-RTA preferences and will allow for it in our empirical application.

2 Empirical Strategy

The value-added augmented tariff theory guides our empirical strategy for identifying the influence of value-added content on policy. The specifications we adopt are directly linked to Equations (11) and (12).

We start by focusing on the role of domestic value added in foreign production. Our first specification treats foreign value added and domestic political economy as nuisance controls to be absorbed by fixed effects. This approach allows us to test the theory in a flexible way and facilitates discussion of the role of RTAs, MFN-censoring, and threats to identification (e.g., endogeneity concerns). To examine foreign value added and domestic political economy explicitly, we then adapt our empirical strategy to lean more strongly on the functional form of the optimal tariff. In this second specification, we include explicit measures of domestic value added, foreign value added, and final goods production (all scaled

[32]The sole exception is recent theoretical work by DeRemer (2016), who develops an augmented definition of reciprocity in the presence of local price externalities.

by imports) as regressors. In a third part, we examine how temporary trade barriers respond to value-added content.

2.1 Domestic Value Added in Foreign Production

Following from Equations (11) and (12), the unilateral applied bilateral tariff can be written as:

$$\begin{aligned} t^{i,\text{applied}}_{xjt} &= \min\{t^i_{xjt}, t^{i,MFN}_{xt}\} \\ \text{with} \quad t^i_{xjt} &= \frac{1}{\epsilon^i_{xj}} + \frac{\delta^i_x p^i_{xt} q^i_{xt} - (1-\delta^i_{x*})\varepsilon^{ri}_{x*} FVA^i_{xt}}{\epsilon^i_{xj}|\lambda^i_{xj}| p^i_{xt} M^i_{xjt}} + \beta_{ijxt} DVA^j_{xit}, \end{aligned} \tag{13}$$

where $\beta_{ijxt} \equiv -\frac{(1+\delta^*_{xi})\varepsilon^{rj}_{xi}}{\epsilon^i_{xj} p^j_{xt} M^i_{xjt}}$.[33] This expression highlights three concerns that we need to address to isolate the impact of DVA^j_{xit} on t^i_{xjt}.

First is the need to control for inverse export supply elasticities ($1/\epsilon^i_{xj}$). Our approach follows the literature by placing empirical restrictions on export supply elasticities. We assume that the inverse export supply elasticity can be decomposed into additive importer-industry-year and exporter-industry-year specific components, which will be absorbed by fixed effects.[34]

Second is the need to control for political economy and foreign value added effects on tariffs, both collected in the second term. Note that the term has both a multilateral component ($p^i_{xt} q^i_{xt}$ and FVA^i_{xt} in the numerator) and a bilateral component ($p^i_{xt} M^i_{xjt}$ in the denominator).[35] To control for these influences, we interact importer-industry-year fixed effects with bilateral, time-varying indicators for import volumes. Specifically, we divide the observed empirical distribution of imports into ten decile bins and form indicators $D_{xijt} \equiv \mathbf{1}(p^i_{xt} M^i_{xjt} \in D)$, where D indexes the set of import decile bins. We interact these decile indicators with the importer-industry-year fixed effects to form importer-industry-year-decile fixed effects.[36]

The third concern is the potential for coefficient heterogeneity on DVA^j_{xit}, principally due to the presence of imports in the denominator of β_{ijxt}. We address this issue here by

[33] As implied by this expression, we treat ε^{rj}_{xi}, ε^{ri}_{x*}, ϵ^i_{xj}, and λ^i_x as time-invariant parameters that will be absorbed in our coefficient estimates.

[34] Broda, Limão and Weinstein (2008) and Ludema and Mayda (2013) assume that export supply elasticities vary by importer and industry, but are identical across partners and through time: $\epsilon^i_{xjt} = \epsilon^i_x$. Our more general parametrization obviously nests this assumption.

[35] Heterogeneity in parameters, elasticities, etc. also generates both multilateral and bilateral components to this term. We do not focus on these, as we abstract from this unobserved heterogeneity in the empirical work and focus exclusively on observables.

[36] These decile interactions also absorb residual variation in bilateral inverse export supply elasticities not picked up by the importer-industry-year or exporter-industry-year fixed effects alone.

substituting $\ln(DVA^j_{xit})$ for DVA^j_{xit}. The logic is as follows. DVA^j_{xit} and bilateral final goods imports are strongly positively correlated in the data, with a raw correlation of 0.75. Because β_{ijxt} is inversely related to the level of bilateral final goods imports, we therefore expect that a \$1 change in DVA^j_{xit} at low levels of DVA^j_{xit} to be more influential than a \$1 change in DVA^j_{xit} at high levels of DVA^j_{xit}. The log function is a convenient transformation of the data that captures this mechanism and so allows us to estimate a homogeneous coefficient for domestic value added.

Based on this discussion, the first specification that we take to the data is:

$$t^i_{xjt} = \Phi_{xit} \times D_{xijt} + \Phi_{xjt} + \beta \ln(DVA^j_{xit}) + e_{xijt}, \tag{14}$$

where Φ_{xit} and Φ_{xjt} are importer-industry-year and exporter-industry-year fixed effects. The DVA sign prediction is $\beta < 0$.

2.1.1 Preferences under vs. outside RTAs

Thus far, our discussion has focused on unilateral tariffs. As discussed in Section 1.4, RTAs may nullify the influence of domestic value added on tariffs. This result depends on whether terms-of-trade externalities are fully eliminated, which may or may not obtain given the institutional design of particular bilateral trade negotiations. Little is known empirically about the extent to which bilateral or regional trade agreements actually neutralize bilateral terms-of-trade externalities. We therefore initially adopt an agnostic approach to the question of whether domestic value added effects are present in RTAs.

We start by pooling data on tariffs under and outside of RTAs, treating Equation (14) as describing all bilateral tariffs. We then (quickly) proceed to test whether domestic value added has similar effects on tariffs inside and outside RTAs. To do so, we augment Equation (14) to allow trade agreements to alter the responsiveness of tariffs to domestic value added, as well as shift the level of tariffs directly.[37] The augmented specification is:

$$\begin{aligned} t^i_{xjt} = {} & \Phi_{xit} \times D_{xijt} + \Phi_{xjt} + RTA_{ijt} \\ & + \beta_1[1 - RTA_{ijt}] \ln(DVA^j_{xit}) + \beta_2 RTA_{ijt} \ln(DVA^j_{xit}) + e_{xijt}, \end{aligned} \tag{15}$$

where RTA_{ijt} is an indicator for whether ij have a bilateral or regional trade agreement in force at date t. If RTAs neutralize bilateral terms-of-trade externalities, then we expect $\beta_2 = 0$. At a minimum, we expect β_2 to be less than β_1, as long as RTAs at least partially

[37]Level effects are implied by the discussion in Section 1.4, in that the additive inverse export supply elasticity term in the unilaterally optimal tariff may disappear under the RTA.

neutralize the bilateral terms-of-trade externality.

2.1.2 Censoring and Endogeneity Concerns

As emphasized in the theory, observed bilateral applied tariffs are effectively censored by each country's multilateral MFN tariff: $t_{xjt}^{i,\text{applied}} = \min\{t_{xjt}^{i}, t_{xt}^{i,MFN}\}$. In our empirical work, we initially ignore this censoring and estimate the response of tariffs to domestic value added via ordinary least squares. These OLS estimates measure the responsiveness of *applied* bilateral tariffs, rather than *optimal* bilateral tariffs, to domestic value added. As is standard, we expect MFN-censoring to attenuate estimates of β toward zero. To estimate the response of optimal tariffs to domestic value added, we correct for MFN-censoring using a Tobit specification.

To establish the causal impact of domestic value added on tariffs, we also need to address the possibility that DVA_{xit}^{j} responds endogenously to final goods tariffs. The concern is that country i's domestic value added embodied in production of final goods in sector x in trading partner j may be decreasing in country i's tariff against imports of x from j. In the model, this would arise because the tariff pushes down the price of the value-added inputs country i supplies for production of x in j.[38] More generally (outside the model), lower tariffs might induce firms to offshore final production stages, leading to higher domestic content in foreign production. Both of these mechanisms induce a negative correlation between $\ln(DVA_{xit}^{j})$ and e_{ijxt}. We use an instrumental variables strategy to address these concerns, and we defer the specifics until we implement the strategy below.

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

Before proceeding, we emphasize one final important point of interpretation. In all specifications that include importer-industry-year fixed effects, including (14) or (15), these fixed effects absorb all variation in multilateral, industry-level MFN tariffs in the data. By construction, our empirical specifications therefore identify the role of domestic value added entirely from deviations between applied bilateral tariffs and MFN tariffs. Put another way, we exploit only bilateral tariff preferences – downward deviations from MFN – to identify the role of DVA on tariff policy. We define bilateral tariff preferences as the (negative) deviation from MFN tariffs, so that $t_{xjt}^{i,\text{applied}} - t_{xt}^{i,MFN} \leq 0$ is the tariff preference granted by country i to country j in sector x at date t. Under this sign convention, more generous bilateral tariff preferences are more *negative* and correspond equivalently to lower bilateral tariff levels.

[38]Relaxing the specific factors assumption would work in the same direction. Tariffs depress foreign final goods output, which may depress the quantity of value-added inputs used, as demonstrated in the general equilibrium extension of the model developed in the appendix.

2.2 Foreign Value Added in Domestic Production

Thus far, we have focused on identifying the influence of domestic value-added in foreign production on tariffs, absorbing all variation in foreign value-added in domestic production via fixed effects. Now we turn to an alternative empirical specification to study these foreign value-added effects directly.

Returning to the unilateral applied bilateral tariff in Equations (11) and (12), we can re-write the optimal bilateral tariff expression as:

$$\begin{aligned} & t_{xjt}^{i,\text{applied}} = \min\{t_{xjt}^i, t_{xt}^{i,MFN}\} \\ & \text{with} \quad t_{xjt}^i = \frac{1}{\epsilon_{xj}^i} + \gamma_{xij}^{IP}\left(\frac{FG_{xt}^i}{p_{xt}^j M_{xjt}^i}\right) + \gamma_{xij}^{FVA}\left(\frac{FVA_{xt}^i}{p_{xt}^j M_{xjt}^i}\right) + \gamma_{xij}^{DVA}\left(\frac{DVA_{xit}^j}{p_{xt}^i M_{xjt}^i}\right), \end{aligned} \tag{16}$$

where $FG_{xt}^i \equiv p_{xt}^i q_{xt}^i$, $\gamma_{xij}^{IP} \equiv \frac{\delta_x^i}{\epsilon_{xj}^i |\lambda_{xj}^i|}$, $\gamma_{xij}^{FVA} \equiv -\frac{(1-\delta_{x*}^i)\varepsilon_{x*}^{ri}}{\epsilon_{xj}^i |\lambda_{xj}^i|}$, and $\gamma_{xij}^{DVA} \equiv -\frac{(1+\delta_{xi}^*)\varepsilon_{xi}^{rj}}{\epsilon_{xj}^i}$.

Equation (16) breaks up the domestic political economy and foreign value added terms and collects imports with other observables to form three ratios. The first is the ratio of domestic final goods production (FG) to bilateral imports, which we refer to as the inverse import penetration ratio (IP-Ratio for short). The second and third are the ratios of foreign value added and domestic value added to bilateral final goods imports, which we refer to as the FVA-Ratio and DVA-Ratio.[39] This ratio specification recognizes that the strength of domestic political economy and foreign value added forces varies bilaterally, due to variation in bilateral imports.

In taking Equation (16) to the data, we confront new econometric concerns. Each of the independent variables has imports in the denominator. Classical measurement error in imports then generates non-classical (multiplicative type) measurement error in the ratios. To deal with this problem, we replace the levels of each ratio with their logs.[40]

Because an important component of the effect of FVA operates at the multilateral level, we also relax the set of fixed effects to use time-series variation, in addition to cross-sectional variation. Specifically, we replace the importer-industry-year fixed effect with importer-industry, importer-year, and industry-year fixed effects. This change re-introduces cross-industry variation within importers over time, with industry trends differenced away, for identification. At the same time, however, a subtle threat to identification emerges. As

[39] A subtle point is that import quantities are evaluated at exporter prices in the first two ratios and at importer prices in the third. We suppress this distinction in our empirical work, as we are not able to measure imports at different prices in the same data set that we use to construct the numerators.

[40] Intuitively, classical measurement error in imports is particularly influential over the value of the ratio when imports are small (equivalently, the ratio is large). Taking logs of the ratios down-weights variation among these large, poorly-measured observations.

discussed in Section 2.1.3, importer-industry-year fixed effects absorb all variation in MFN tariffs. To ensure that MFN tariff variation does not drive our results with this new fixed effects specification, the dependent variable is explicitly defined as tariff preferences in each specification. Thus, we adopt the following specification:

$$t^i_{xjt} - t^{i,MFN}_{xt} = \Phi_{xi} + \Phi_{it} + \Phi_{xt} + \Phi_{xjt} + \gamma^{IP} \ln\left(\frac{FG^i_{xt}}{IM^i_{xjt}}\right) + \gamma^{DVA} \ln\left(\frac{DVA^j_{xit}}{IM^i_{xjt}}\right) + \gamma^{FVA} \ln\left(\frac{FVA^i_{xt}}{IM^i_{xjt}}\right) + e_{xijt}, \quad (17)$$

where the Φ terms again denote fixed effects and IM^i_{xjt} represents bilateral final goods imports. The sign predictions are $\gamma^{IP} \geq 0$, $\gamma^{DVA} < 0$, and $\gamma^{FVA} < 0$ (provided the political strength of foreign value added is not too high). As robustness check, we also estimate a variant of this specification with importer-industry-year fixed effects.

2.2.1 Preferences under vs. outside RTAs

In taking the specification in Equation (17) to data, we again confront concerns about tariffs inside vs. outside RTAs. While we expect that tariffs within bilateral or regional agreements will continue to respond to domestic political economy concerns, since they are independent of cross-border externalities, the effect of FVA is less clear cut. But since there is nothing in the existing literature to suggest directly that RTAs will eliminate *all* price externalities (beyond simply the terms of trade), we initially use all bilateral tariff variation, both within and outside of RTAs, to look for FVA effects. More subtly, the theory also suggests that the coefficients attached to the inverse penetration ratio and foreign value added may differ inside versus outside of RTAs. It also implies that within RTAs, the additive inverse supply elasticity term may disappear, due to neutralization of the term-of-trade externality.

In light of these differences, we analyze FVA effects outside and inside RTAs in several steps. First, we pool all tariffs and estimate a single (homogeneous) coefficient on the IP-Ratio, DVA-Ratio, and FVA-Ratio.[41] Second, we break up the coefficients on each of the ratios, as we did in the previous section. Third, we re-estimate Equation (17) in the subsample of non-RTA tariffs only.

[41] In this regression, we also include an indicator variable for RTAs, which absorbs level differences in tariffs inside versus outside agreements.

2.2.2 Censoring and Endogeneity Concerns

The censoring concerns in this specification mirror those outlined in Section 2.1.2, and so we implement the same Tobit correction. In contrast, new endogeneity concerns arise in this empirical specification. In addition to domestic value added, the levels of domestic production, imports, and foreign value added may be correlated with the residual variation in tariffs. Most importantly, foreign value added may increase with tariffs. In our model, the price of foreign value-added inputs rises mechanically with the tariff. Outside the model, one might (also) be concerned that foreign firms engage in "tariff jumping," shifting to local final production (using imported inputs) in high tariff sectors/countries.[42] If so, the coefficient estimate on the FVA-Ratio will be biased upwards, which could lead us to find a zero/positive coefficient erroneously.[43] We discuss this issue further when we turn to IV below.

3 Data

This section describes how we construct our data on the value-added content of production and bilateral trade policy. It also offers a first peek at the data.

3.1 Value-Added Content of Final Goods Production

To calculate our measures of the value-added content embodied in final goods production (DVA and FVA), we use data from the World Input-Output Database (WIOD).[44] It contains an annual sequence of global input-output tables for the 1995-2009 period covering 35 industries across 27 EU countries and 13 other major countries.

Following Los, Timmer and de Vries (2015), we use these data to compute the national origin of value added contained in the final goods that each country produces. Intuitively, the global input-output table enables one to trace backwards through the production process

[42] Alternatively, by protecting domestic producers and raising the level of domestic production, high tariffs could mechanically raise the total amount of foreign value added used by domestic industry. This is not a concern with the log specification we implement, since $\ln\left(FVA^i_{xt}/IM^i_{xjt}\right)$ is purged of $\ln\left(FG^i_{xt}/IM^i_{xjt}\right)$. To be explict, let us write $FVA^i_{xt} = fva^i_{xt}FG^i_{xt}$, where fva^i_{xt} is the share of foreign value added in domestic production. Then, $\ln(FVA^i_{xt}/IM^i_{xjt}) = \ln(fva^i_{xt}) + \ln(FG^i_{xt}/IM^i_{xjt})$. Since we control for $\ln(FG^i_{xt}/IM^i_{xjt})$ directly, the FVA effect is identified entirely off variation in the share of foreign value added ($\ln(fva^i_{xt})$) over time. Tariff jumping could, however, influence this share.

[43] An alternative story that could work in the opposite direction is that tariff liberalization under RTAs could induce higher FVA if these agreements create "regional factories" [Baldwin and Lopez-Gonzalez (2015)]. Our control for RTAs dampens this potential source of bias and our IV approach (discussed shortly) mitigates it further.

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

to assess the value and identify the national origin of the intermediate inputs used (both directly and indirectly) to produce each country's final goods. With this information, one can (for example) compute the amount of Canadian value added embodied in US-produced autos. We describe the exact calculations in Appendix B. We construct value-added contents for 14 "countries" (13 non-EU countries, plus the composite EU region) and 14 industries, which are listed in Table 1.[45]

3.2 Bilateral Tariffs

We construct bilateral, industry-level tariffs on final goods for four benchmark years: 1995, 2000, 2005, and 2009. We briefly describe the data sources and procedure here; see Appendix B for details.

We start with national government, product-level tariff schedules collected by UNCTAD (TRAINS) and the WTO, which we obtain via the World Bank's WITS website [http://wits.worldbank.org]. Multilateral MFN applied tariffs are typically available in the WTO data, while bilateral applied tariffs are from TRAINS. Combining these sources and aggregating product lines yields a data set of bilateral tariffs at the Harmonized System (HS) 6-digit level.

To identify final goods tariffs in the data, we use the Broad Economic Categories (BEC) classification. We retain HS 6-digit categories classified as consumption and capital goods, discarding both mixed use and intermediate input categories.[46] We then concord these HS 6-digit final goods categories to WIOD industries using a cross-walk from HS categories to ISIC Revision 3 industries to the WIOD industry codes. We take simple averages across HS categories within each industry to measure industry-level applied bilateral and MFN tariffs.

3.3 Temporary Trade Barriers

We obtain data on temporary trade barriers (TTBs) — antidumping, safeguards, and countervailing duties — from the World Bank's Temporary Trade Barriers Database [Bown (2014)]. 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.[47] Following Trefler (1993) and Goldberg and Maggi (1999), among others, we con-

[45]We exclude two industries from the raw WIOD data: (1) Mining and Quarrying, which contains no final end use products, and (2) Coke, Refined Petroleum and Nuclear Fuel, which contains only one final end use HS 6-digit category.

[46]Roughly 40 percent of the HS 6-digit codes in the raw data are classified as final goods, which corresponds to the value share of final goods in world trade.

[47]The data cover all countries in Table 1, except for Russia. In our analysis of TTBs, we exclude China and Taiwan because nearly all of their TTBs are imposed on intermediate inputs.

struct import coverage ratios to track TTB use over time. These coverage ratios measure the stock of accumulated bilateral TTBs imposed by each importer against individual exporters in each industry and year.[48]

As in the tariff data, we begin with TTB data at the product-level, aggregate to the HS 6-digit level, extract HS 6-digit categories that correspond to final goods using the BEC classification, 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. We construct TTB coverage ratios for each year separately (1995, 2000, 2005, and 2009), which allows for both the imposition of new TTBs and removal of existing TTBs over time.

3.4 First Peek at the Data

Before moving to formal analysis, we pause to introduce the bilateral tariff data, since their use is relatively new to the literature. We first review a few salient facts about bilateral tariff preferences, and then relate observed tariff variation to value-added content in an illustrative case to fix ideas.

Tariff Preferences Our identification strategy exploits differences between bilateral applied tariffs and applied MFN rates. Bilateral applied tariffs differ from MFN tariffs because countries offer preferential (lower-than-applied MFN) tariffs to selected partners under various preference schemes. We provide a summary description of these schemes and their relative importance here, with details provided in Appendix B.

There are four main sources of tariff preferences in our data. The first is the Generalized System of Preferences (GSP), which accounts for the majority of preferences. It is an explicitly unilateral preference scheme, in which developing countries receive preferential treatment from high-income importers.[49] An important feature of the GSP program is that 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.

[48] In constructing these coverage ratios, we follow the approach described in Bown (2011). 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.

[49] In our data, 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.

Free trade agreements and customs unions, authorized under WTO Article XXIV, are a second source of preferences. These agreements embody a high degree of cooperation, in that bilateral preferences are both extensive in scope and meaningfully symmetric across partners. As a result, we treat all Article XXIV in our data as *potentially* cooperative bilateral or regional trade agreements. That said, two points about RTAs are worth emphasizing. The first is that carve-outs in Article XXIV agreements are pervasive.[50] Second, there are often asymmetric and prolonged phase-in periods, during which preferences are only partially implemented. As a result, many products/industries continue to face positive tariffs even after Article XXIV come into force. In our data, about 50 percent of RTA tariffs are greater than zero.

The third source of preferences derives from trade agreements struck between developing countries under the auspices of the WTO's Enabling Clause. These include 'Partial Scope Agreements' (e.g., the Global System of Trade Preferences and the Asia-Pacific Trade Agreement), as well as some bilateral agreements.[51] Lastly, a handful of idiosyncratic programs and one-off preferences constitute the fourth and final source of preferences in our data.

In the data, there is significant variation in tariff preferences across country pairs and sectors and over time. Exporters receive preferential treatment in about one-third of our observations. Conditional on receiving preferences, the median difference between the applied bilateral tariff and the applied MFN tariff is about -2 percentage points, with a 10th-90th percentile range of $[-6.21, -0.13]$. We plot the distribution of preferences in Figure 1. Decomposing the sources of these preferences, GSP programs account for 69 percent of observed preferences, RTAs account for an additional 20 percent of preferences, and other unilateral tariff schemes account for the remaining 11 percent of preferences.

Tariff Preferences and Domestic Value Added Before putting the pieces together formally, we open with a simple scatter plot, which both illustrates the variation in the data and motivates a number of concerns that we address in the subsequent empirical analysis.

Figure 2 plots bilateral tariff preferences ($t^i_{xj} - t^{i,MFN}_x$) against (log) bilateral domestic value added in foreign production for high-income importers against emerging market exporters in 2005. The top panel focuses on the Textiles and Apparel industry, where both the scope for and use of tariff discretion is high. The bottom panel depicts the same correlation for manufacturing as a whole, where the y-axis is the simple mean preference across all man-

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

[51] The agreements typically cover only a small share of products (roughly 4 to 500 HS 6-digit categories in our data). As such, these preferences appear highly discretionary.

ufacturing industries and the x-axis is total domestic value added in foreign manufacturing.

We note two key points about the figure.[52] First, there is a negative correlation between applied tariffs and $\ln(DVA)$, which is consistent with the prediction that importers grant larger preferences to countries that use a lot of domestic (importer) value added in production of their final goods. Roughly speaking, this is the correlation we are estimating below. Second, there is an obvious censoring problem in the figure, as indicated by the mass point at zero preference. The inability to raise tariffs above the MFN rate against countries in which domestic value added is low (the left end of the x-axis) will tend to bias the simple correlation toward zero.

4 Results I: Tariffs

Following the structure outlined in Section 2, we start by estimating how bilateral applied tariffs respond to domestic value added in foreign production. We then turn to an alternative specification to examine how foreign value added in domestic production influences tariffs.

4.1 Domestic Value Added in Foreign Final Goods

Table 2 presents benchmark OLS results based on Equation (14). Panel A of the table contains results with importer-industry-year-decile fixed effects, and Panel B includes importer-industry-year fixed effects. Both panels also include exporter-industry-year fixed effects.

We start in columns (1) and (5) by regressing all bilateral tariffs on the log of domestic value added in foreign final goods production, $\ln(DVA^{j}_{xit})$. The correlation is negative, indicating that applied bilateral tariffs are lower when bilateral DVA is high (consistent with the theoretical prediction). In columns (2) and (6), we add binary indicators for the existence of bilateral or regional trade agreements (RTAs). This RTA indicator absorbs variation in both bilateral tariffs and bilateral DVA across pairs with and without RTAs, which tend to have both low tariffs and high DVA relative to non-RTA pairs. Controlling for RTAs attenuates the DVA coefficient, but the estimated influence of domestic value added embodied in foreign production remains highly significant. Finally, comparing results across panels, note that estimates with alternative fixed effects are similar in magnitude,

[52] Two additional comments are as follows. A number of observations in the lower right area are cases where the country pair has a trade agreement in place, and this motivates our attention to RTAs below. Furthermore, looking at the upper right portion of the figure, it is evident that China receives relatively few preferences despite the high foreign content of its exports. This suggests that there may be un-modeled political economy forces that lead particular exporters (in particular, China) to receive fewer preferences than others; systematic exporter-level influences will be absorbed in the fixed effects in our estimation.

though estimates with importer-industry-year-decile fixed effects appear to be slightly more conservative.

To interpret the magnitudes, it is typical for $\ln(DVA^j_{xit})$ to vary by roughly 5 log points across bilateral partners within a given importer and industry.[53] The point estimate in column (2) is -0.5. Thus, moving from low to high DVA partners yields a reduction of 2.5 percentage points in *observed* applied tariffs. Since the median tariff is around 8 percent in our data, this represents about a 30 percent reduction in the typical tariff level.

4.1.1 Tariffs Within vs. Outside RTAs

Recognizing that the theory makes distinct predictions for tariffs set inside versus outside RTAs, we estimate specifications with heterogeneous coefficients on DVA inside versus outside RTAs. In columns (3) and (7) of Table 2, we take an agnostic view, estimating separate coefficients inside versus outside RTAs. In columns (4) and (8), we *impose* the assumption that the inside-RTA coefficient is zero, as implied by theory if indeed RTAs eliminate all terms-of-trade motivations for final goods.

Looking at column (3), DVA is associated with lower applied bilateral tariffs set outside RTAs, while tariffs set inside RTAs are uncorrelated with DVA. Imposing the restriction that the correlation is exactly zero, in columns (4) and (8), has no appreciable impact on the DVA estimate outside RTAs. In Appendix C, we repeat this analysis using an alternative, broader definition of RTAs that includes some non-Article XXIV trade agreements. The results using this broader definition are essentially the same.

Based on these results, we focus exclusively on the non-RTA sample in the remainder of this section. Table 3, Panel A repeats the OLS estimation in the non-RTA sample of tariffs. The coefficients on DVA are again negative and significant.

Censoring and Endogeneity We now turn to estimates that correct for censoring of bilateral tariffs due to application of the MFN rule and that address endogeneity concerns.

The OLS estimates presented above describe how *applied* tariffs respond to DVA. They are likely to underestimate how strongly *optimal* tariffs respond to DVA, since the MFN rule prohibits upward deviations in bilateral tariffs. To examine the impact of this censoring, we estimate a one-sided Tobit model in column (3) of Table 3.[54] As expected, the coefficient on

[53] This is the median difference between maximum and minimum values across the 13 trading partners in each importer-industry-year cell. The inter-quartile range is roughly 3.6 log points.

[54] Two details are worth noting. First, we estimate a Tobit with importer-industry-year fixed effects here, rather than importer-industry-year-decile fixed effects. As we showed previously, OLS estimates with the different sets of fixed effects are quite similar. Further, when we move to Tobit, we must drop observations that are perfectly predicted by the fixed effects, where the perfect prediction arises due to some importer-

domestic value added rises (in absolute value), roughly tripling to -0.77. Given the 'typical' 5 log point spread in DVA across partners, this revised estimate implies that optimal tariffs are roughly 3.85 percentage points (48 percent of the median tariff) lower for partners with high versus low DVA.

As noted earlier, the possible endogenous response of DVA^i_{xjt} to t^i_{xjt} is a threat to causal identification. To address this endogeneity concern, we instrument for DVA in two different ways.

We first instrument for $\ln(DVA^i_{xjt})$ using domestic value added from i used in the services sector in country j, which we denote $\ln(DVA^i_{zjt})$ and verbally refer to as DVA-in-Services. This instrument is relevant, since there are likely common supply-side factors that make i an attractive input supplier for j across many sectors. It is also valid, in that t^i_{xjt} has no direct influence over value-added input use by the service sector in country j, and so $\ln(DVA^i_{zjt})$ is plausibly uncorrelated with the tariff equation residual. As a concrete example, the identification assumption is that the amount of US value added used by India in the services sector is not determined by the US import tariff on textiles from India.

Results using this DVA-in-Services instrument are presented in Panel B of Table 3. Not only do the OLS results from Panel A hold up, but they are actually strengthened when when we instrument for domestic value-added content. This suggests that the mechanical endogeneity concerns described above are not inflating our estimates, and if anything that countervailing concerns – such as measurement error – may be biasing the non-IV results toward zero.

To corroborate this analysis, we examine the same set of IV-regressions for a second, alternative instrument: the level of domestic value added in foreign production in 1970, which we denote $\ln(DVA^i_{sj,1970})$ and verbally refer to as DVA-in-1970. This instrument is plausibly valid in that 1970 predates the introduction of the preference schemes observed in our data; thus, DVA-in-1970 cannot mechanically be a function of contemporary tariff preferences.[55] We present IV results using this second instrument in Panel C of Table 3. Not

industry-year or exporter-industry-year cells having no tariff preferences. The Tobit sample is therefore smaller than the baseline (OLS) sample. Using importer-industry-year fixed effects (instead of importer-industry-year-decile fixed effects) minimizes this reduction in sample size. Second, while there is some additional censoring of tariffs at zero, it is not quantitatively important – the mass point of tariffs at the upper MFN rate dwarfs the mass point at zero. Two-sided Tobit estimates are typically slightly larger in absolute value than the one-sided estimates, so the one-sided estimates here are conservative.

[55] Using the data set developed in Johnson and Noguera (2014), we measure bilateral DVA-in-1970 for two composite sectors: agriculture and manufacturing. Due to missing data for Russia and Taiwan, the sample for which we can construct this instrument is roughly 30 percent smaller than our baseline sample. This is one cost of using this instrument. A second cost is that there is no time-variation in the instrument, in contrast to DVA-in-Services. On the other hand, this cost is counterbalanced by additional cross-industry variation in this instrument. In the end, this instrument isolates different exogenous variation than does the DVA-in-Services instrument.

only does the DVA coefficient remain and significant after instrumenting, the IV estimate is again is larger in absolute value than the OLS estimate.

All together, these results point to a causal relationship running from domestic value added in foreign production to tariffs. In Appendix C, we examine a number of alternative specifications with additional bilateral control variables (e.g., distance, colonial history, etc.) that further bolster this interpretation.

Unpacking non-RTA Preferences We now examine whether the role of DVA differs depending on the nature of the tariff preference program under which tariffs are set. As noted previously, the GSP program is an important source of bilateral tariff preferences in our data. It is also an especially useful source of variation, in that it is explicitly unilateral. According to theory, we should therefore expect to find that GSP-related preferences respond to DVA. On the other hand, it is less clear how other non-GSP preferences (some of which are more plausibly cooperative in nature, others of which are not) will respond to DVA.

To explain how we analyze GSP versus non-GSP preferences, we briefly review how the GSP program operates. By design, GSP operates only among a subset of country pairs – namely, between "advanced" importing countries that grant preferential access to "developing" exporting countries under the Enabling Clause. We define the set of potential *GSP-granting* countries as those that grant GSP access to at least one other country in our sample. Likewise, we define the set of potential *GSP-receiving* countries as those that receive GSP access from at least one other country in our sample. Each GSP-granting country has discretion over the set of countries and sectors included in its GSP program, as well as the level of its tariff preferences.[56]

To examine how the GSP program operates in our data, we define an indicator (in the non-RTA sample) that identifies which country pairs are potentially eligible for GSP preferences: $GSP_{ij} = \mathbf{1}\left(i \in \textit{GSP-granting}, j \in \textit{GSP-receiving}\right)$. For country pairs with $GSP_{ij} = 1$, the GSP program itself accounts for essentially all observed preferences in our data. However, not all pairs with $GSP_{ij} = 1$ actually have lower-than-MFN tariffs, since some potentially GSP eligible exporters and sectors are excluded by GSP-granting countries.[57] For country pairs

[56] In our data, we observe only a uniform tariff preference applied to all countries included in each importer's GSP program. In reality, countries have scope to vary tariff preferences bilaterally, via discretionary application of limits on GSP access (e.g., competitive needs limitations). We do not observe these bilaterally targeted preferences, and so our data likely understate the true degree of discretion that countries exercise. As such, one might expect our results to be attenuated.

[57] For example, the US does not grant China preferences in its GSP program, while the EU does grant China preferences in its GSP program. Therefore, while both $GSP_{\text{USA,CHN}} = 1$ and $GSP_{\text{EUN,CHN}} = 1$, we only observe tariff preferences in only the EUN-CHN case. Further, there is time variation in the application of GSP preferences over time, as in an ij pair with $GSP_{ij} = 1$ may have preferential tariffs in one year but not another year in the sample. We use both this time variation and cross-sectional variation for identification.

with $GSP_{ij} = 0$, non-GSP preference schemes are the source of observed tariff preferences.

In Table 4, we re-estimate our baseline DVA regressions allowing the coefficient on DVA to vary depending on whether the country-pair is potentially eligible for GSP. As it turns out, tariffs respond to domestic value added in both the GSP eligible and GSP ineligible samples. In the pooled sample with heterogeneous coefficients, DVA has a slightly stronger effect on observed tariffs for GSP-eligible pairs. This difference fades in Panels B and C when we split the sample, allowing the fixed effects to vary across groups.

The conclusion is that DVA influences tariffs throughout the non-RTA sample. On the one hand, DVA influences preferences granted under the GSP program. This is comforting, since we are confident that there is significant unilateral discretion over bilateral tariffs in this particular institutional context. On the other hand, we also detect DVA effects in non-GSP preferences, which implies that other preference regimes (e.g., Partial Scope Agreements) appear to enable countries to manipulate bilateral tariffs in response to terms-of-trade concerns as well.

4.2 Foreign Value Added in Domestic Final Goods

We now move to specifications based on Equation (17) – in which ratios of final goods production, domestic value added, and foreign value added to bilateral imports appear separately on the right hand side – to identify the influence of foreign value added in domestic production on bilateral tariffs.

In Table 5, we estimate Equation (17) using the sample of both RTA and non-RTA tariffs. This specification allows for the possibility that FVA effects may be found both inside and outside RTAs, even if DVA effects are not. This specification is also useful for comparison to Table 2. The baseline specification in column (1) includes the fixed effects specified in Equation (17), together with a RTA indicator to control for level differences in tariffs and value-added contents inside versus outside RTAs. We also estimate a supplemental specification in column (2) with importer-industry-year fixed effects, which replaces $\Phi_{xi} + \Phi_{it} + \Phi_{xt}$ with Φ_{xit} in (17). With the importer-industry-year fixed effects, we can identify only γ^{DVA} and $(\gamma^{IP} + \gamma^{FVA})$ in this case, where $(\gamma^{IP} + \gamma^{FVA})$ is identified by variation in bilateral imports across partners. Columns (3) and (4) repeat the exercises in columns (1) and (2), correcting for MFN censoring via a Tobit regression.

Starting with DVA, we find a strong negative relationship between the log DVA-Ratio and applied tariffs, consistent across specifications, and similar in magnitude to those estimated previously in Table 2. The coefficient on the FVA-Ratio is negative in both the OLS and Tobit specifications. It is significant at the 5 percent level in the OLS specification and modestly insignificant at conventional levels in the Tobit specification. Finally, note that the coefficients on the inverse import penetration ratio are also positive, consistent with the existing literature on the political economy of trade policy.

Before proceeding, we pause to comment on endogeneity concerns in this specification. As noted in Section 2.2.2, the primary new concern is that foreign value added may depend positively tariffs, which would bias the FVA coefficient upward (toward zero/positive values). We generally find negative OLS coefficients on FVA. Therefore, the sign result we emphasize here is not plausibly explained by endogeneity; if anything, the magnitude of the OLS coefficient may be understated due to endogeneity. To examine endogeneity concerns more formally, we provide instrumental variables estimates of Equation (17) in Appendix C. We find that the IV estimate of the FVA coefficient is also negative and typically larger (in absolute value) than the OLS coefficient, consistent with this argument.

Recalling again the distinction between tariffs within versus outside RTAs, we re-estimate these two specifications allowing for coefficient heterogeneity across these groups and present the results in Table 6. Consistent with our previous results, we find that tariffs fall with DVA outside RTAs, but we cannot reject that the coefficient is zero inside these agreements. In contrast, the opposite pattern holds for the foreign value added results. FVA effects are strongest inside RTAs, and they are statistically indistinguishable from zero for tariffs set outside RTAs, both in the pooled sample and in Panel C where re-estimate Equation (17) in the non-RTA sample only. In Appendix C, we show that the FVA effect outside RTAs is estimated to be negative when we instrument for FVA, consistent with endogeneity attenuating the FVA coefficient in this subsample.

We find it striking that FVA effects are so strong inside RTAs, despite our null results concerning DVA effects inside the same set of RTAs. Value-added content matters both inside and outside these agreements, although how it matters seems to differ in a manner that is roughly consistent with the neutralization of terms-of-trade motives for final goods. Regarding magnitudes, it is worth pointing out that the FVA point estimates here are economically sensible. For example, the Tobit estimate is that a one log point change in FVA lowers tariffs inside RTAs by 5.38 percentage points. Historically, FVA grew by roughly 0.5 log points over the 1995-2009 period, therefore this implies a fall in optimal tariffs of about 2.7 percentage points (about one-third the size of the median bilateral tariff).

5 Empirical Results II: Temporary Trade Barriers

In addition to bilateral tariffs, governments use non-tariff barriers to restrict imports. In this section, we examine whether value-added content influences use of these policies as well.

We focus on a specific class of non-tariff barriers, referred to collectively as temporary trade barriers (TTBs), which include antidumping, safeguards, and countervailing duties.

Temporary trade barriers are a natural testing ground for the value-added mechanisms indicated by theory. Countries have wide latitude under WTO rules to use TTBs, and they can be targeted at particular trading partners and products.[58] Moreover, 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)]. Finally, prior research has found that non-tariff barriers generally, and temporary trade barriers in particular, appear to respond to optimal tariff considerations, which suggests TTBs may offer fertile territory for exploring the effects of DVA in particular.[59]

In examining TTB use, our empirical specifications follow our earlier approach for bilateral tariffs. The principal modification is that we use lagged measures of value-added content in our regressions. The reason is that the TTB import coverage ratio (the dependent variable) measures the stock of TTBs in force, not the flow of new TTB imposed/removed (see Section 3.3). 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.

Table 7 presents ordinary least squares estimates for TTB coverage ratios.[60] Similar to previous tables, 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

[58] 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.

[59] 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)].

[60] TTB coverage ratios have a mass point at zero. While we could use limited dependent variable methods to take this into account, we focus on OLS results here for several reasons. First, TTBs are a rare event in the data, occurring in only 6 percent of our importer-exporter-industry-year observations. Standard binary outcome models (e.g., Probit and Logit) are 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 is an untenable assumption in our context. Second, as a practical matter, presuming that zero TTB coverage ratios conform to our basic theoretical predictions, OLS would then understate the true role of value-added content in shaping TTBs (coefficients of interest would be biased toward zero). Thus, OLS is a robust and likely conservative approach to characterizing our data.

importer-industry-year and exporter-industry-year fixed effects. 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. Further, the coefficient on the inverse import penetration ratio is positive. These results are broadly consistent with our results for tariffs.[61]

To better understand these results, we exploit auxiliary information about how countries use TTBs in practice. In the data, China is the exporter in approximately 30 percent of the importer-exporter-industry-year cells in which TTBs are observed as being used (i.e., with nonzero coverage ratios), roughly three times as many as the next highest exporter. Further, it is very rare during this particular time period for countries to impose TTBs in a given sector without 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 possibility, we separately examine how value-added content influences TTB use depending on whether China is the exporting country. To this end, we interact the value-added content measures with indicators for whether China is the exporter, and then re-estimate the specifications from Panel A.[62]

The results are reported in Panel B of Table 7. The main result is that TTB coverage ratios are roughly four times as sensitive to domestic value-added content when China is the exporter. Thus, domestic value added in Chinese production appears to strongly discourage protectionist use of TTBs against China. Importantly, this effect is not limited to China. TTB use is also significantly negatively correlated with domestic value added for other exporters as well. In contrast to DVA, foreign value appears to be equally influential over TTB against China versus all other exporters. This is also reasonable: FVA effects operate at the multilateral level in theory, so it is sensible that their empirical influence manifests itself at the multilateral level as well.

6 Conclusion

This paper takes a first look at the role of global supply chains in shaping trade policy. Global supply chains erode the link between the location in which final goods are produced

[61] One minor point is that we cluster in this table on importer-exporter-industry, in contrast to previous tables. The reason is that TTB policy decisions are independent across industries. This contrasts with tariff policy, where tariffs may be correlated across sectors for institutional reasons – e.g., due to signing bilateral trade agreements that cover multiple sectors, or due to the application of exporter-specific exemptions in the GSP program. The significance levels of our main results in columns (1) and (3) are robust to clustering more conservatively by importer-exporter pair, as we did in previous tables.

[62] Note that we do not explicitly include an indicator variable for whether China is an exporter in the regression, since it is redundant given the exporter-industry-year fixed effects included in these regressions.

and the nationality of the value-added content embodied in those goods. Because import tariffs are by definition applied based on the location from which goods are imported, global supply chains modify optimal tariff policy.

When domestic content in foreign final goods is high, a country has a reduced incentive to manipulate its (final goods) terms-of-trade, leading to lower import tariffs. When foreign content in domestic final goods is high, some of the benefits of protection are passed back up the supply chain to foreign suppliers. This mechanism further lowers optimal tariffs. We find evidence in support of both of these predictions in two distinct settings: when countries discriminate across trading partners by lowering protection through bilateral tariff preferences, and when countries discriminate by raising protection through the adoption of temporary trade barriers. These results demonstrate the empirical importance of specific channels through which global supply chains shape governments' trade policy choices.

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 the issue of optimal input tariffs. In future work, we plan to tackle the more complex problem of how governments could jointly set tariffs on final goods and intermediate inputs to protect and promote domestic value added. The analysis we have conducted here is a key input into that general problem, describing how optimal final goods tariffs depend on value-added content. Because input tariffs can change value-added contents, they are then naturally tied to final goods tariffs.

Second, in our empirical analysis, we have focused on *bilateral* tariff preferences and TTB coverage ratios. This empirical setting distinguishes our work from the bulk of the empirical 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.

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Table 1: 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 industries. We exclude Mining and Quarrying (WIOD industry 2) and Coke, Refined Petroleum and Nuclear Fuel (WIOD industry 8) in all our analysis.

Table 2: Bilateral Tariffs and Domestic Value Added in Foreign Production

Panel A: Importer-Industry-Year-Decile & Exporter-Industry-Year Fixed Effects				
	(1)	(2)	(3)	(4)
Log DVA: $\ln(DVA^j_{xit})$	-0.92***	-0.46***		
	(0.27)	(0.16)		
Log DVA Outside RTAs: $[1-RTA_{ijt}]\times\ln(DVA^j_{xit})$			-0.55***	-0.66**
			(0.19)	(0.32)
Log DVA Inside RTAs: $RTA_{ijt}\times\ln(DVA^j_{xit})$			0.26	
			(0.42)	
Reciprocal Trade Agreement: RTA_{ijt}		-3.68***	-7.86**	-7.00***
		(0.82)	(3.28)	(2.07)
Observations	8,853	8,853	8,853	8,853
R-Squared	0.988	0.990	0.991	0.991

Panel B: Importer-Industry-Year & Exporter-Industry-Year Fixed Effects				
	(5)	(6)	(7)	(8)
Log DVA: $\ln(DVA^j_{xit})$	-1.32***	-0.61***		
	(0.35)	(0.21)		
Log DVA Outside RTAs: $[1-RTA_{ijt}]\times\ln(DVA^j_{xit})$			-0.69***	-0.64***
			(0.22)	(0.24)
Log DVA Inside RTAs: $RTA_{ijt}\times\ln(DVA^j_{xit})$			-0.12	
			(0.46)	
Reciprocal Trade Agreement: RTA_{ijt}		-4.53***	-7.39***	-7.84***
		(0.91)	(2.80)	(1.71)
Observations	8,853	8,853	8,853	8,853
R-Squared	0.967	0.974	0.974	0.974

Note: The regression specification is based on Equation (14). The dependent variable in all columns is the applied bilateral tariff of country i in industry x against exporter j at time t: t^i_{xjt}. Log DVA ($\ln(DVA^j_{ijt})$) is domestic value added from the importing country(i) embodied in final production in industry x in the exporting country (j). Reciprocal Trade Agreement (RTA_{ijt}) is an indicator that takes the value one if i and j have a RTA in force in year t. Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

Table 3: Bilateral Tariffs and Domestic Value Added in Foreign Production: Censoring and Instrumental Variables Estimation in Non-RTA Sample

Panel A: OLS vs. Tobit			
	OLS		Tobit
	(1)	(2)	(3)
Log DVA: $\ln(DVA^j_{xit})$	-0.17**	-0.24***	-0.77***
	(0.068)	(0.079)	(0.23)
Observations	8,187	8,187	4,431
R-Squared	0.997	0.994	

Panel B: Instrumental Variables (DVA-in-Services)			
	Linear-IV		Tobit-IV
	(4)	(5)	(6)
Log DVA: $\ln(DVA^j_{xit})$	-0.21***	-0.28***	-0.80***
	(0.053)	(0.082)	(0.26)
Observations	8,187	8,187	4,431
R-Squared	0.997	0.994	

Panel C: Instrumental Variables (DVA-in-1970)			
	Linear-IV		Tobit-IV
	(7)	(8)	(9)
Log DVA: $\ln(DVA^j_{xit})$	-0.87***	-1.22***	-2.74***
	(0.16)	(0.26)	(0.93)
Observations	6,055	6,055	3,280
R-Squared	0.997	0.992	

Column Fixed Effects (all panels)			
Importer-Industry-Year-Decile	Y	N	N
Importer-Industry-Year	N	Y	Y
Exporter-Industry-Year	Y	Y	Y

Note: The regression specification is based on Equation (14). The dependent variable in all columns is the applied bilateral tariff of country i in industry x against exporter j at time t: t^i_{xjt}. Log DVA ($\ln(DVA^j_{ijt})$) is domestic value added from the importing country(i) embodied in final production in industry x in the exporting country (j). Sample includes only countries pairs and years with no reciprocal trade agreement in force. Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

Table 4: Bilateral Tariffs and Domestic Value Added in Foreign Production: GSP Eligible vs. GSP Ineligible Country Pairs

Panel A: No RTA Sample				
	OLS		Linear-IV	
	(1)	(2)	(3)	(4)
Log DVA (GSP ineligible): $GSP_{ij} \times \ln(DVA^j_{xit})$	-0.13*	-0.19**	-0.14***	-0.18**
	(0.07)	(0.077)	(0.06)	(0.08)
Log DVA (GSP eligible): $[1-GSP_{ij}] \times \ln(DVA^j_{xit})$	-0.18**	-0.26***	-0.25***	-0.32***
	(0.07)	(0.09)	(0.06)	(0.09)
GSP eligible: GSP_{ijt}	-0.64***	-0.58**	-0.42**	-0.40
	(0.24)	(0.23)	(0.17)	(0.26)
R-Squared	8,187	8,187	8,187	8,187
Observations	0.998	0.994	0.998	0.994

Panel B: No RTA & GSP Eligible Sample				
	OLS		Linear-IV	
	(5)	(6)	(7)	(8)
Log DVA: $\ln(DVA^j_{xit})$	-0.15	-0.22*	-0.16***	-0.23**
	(0.11)	(0.11)	(0.06)	(0.10)
R-Squared	3,039	3,039	3,039	3,039
Observations	0.999	0.995	0.998	0.994

Panel C: No RTA & GSP Ineligible Sample				
	OLS		Linear-IV	
	(9)	(10)	(11)	(12)
Log DVA: $\ln(DVA^j_{xit})$	-0.18	-0.21*	-0.22***	-0.23**
	(0.11)	(0.12)	(0.07)	(0.11)
R-Squared	5,148	5,148	5,148	5,148
Observations	0.998	0.996	0.998	0.996

Column Fixed Effects (all panels)				
Importer-Industry-Year-Decile	Y	N	Y	N
Importer-Industry-Year	N	Y	N	Y
Exporter-Industry-Year	Y	Y	Y	Y

Note: The regression specification is based on Equation (14). The dependent variable in all columns is the applied bilateral tariff of country i in industry x against exporter j at time t: t^i_{xjt}. Log DVA ($\ln(DVA^j_{ijt})$) is domestic value added from the importing country(i) embodied in final production in industry x in the exporting country (j). See Section 4.1.1 for the definition of GSP Eligibility. No RTA Sample includes only countries pairs and years with no reciprocal trade agreement in force. Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

Table 5: Bilateral Tariffs and Value-Added Content

	OLS		Tobit	
	(1)	(2)	(3)	(4)
Log DVA-Ratio: $\ln(DVA^j_{xit}/IM^i_{xjt})$	-0.48***	-0.55***	-1.32***	-1.40***
	(0.18)	(0.21)	(0.43)	(0.46)
Log FVA-Ratio: $\ln(FVA^i_{xt}/IM^i_{xjt})$	-0.31**		-0.51	
	(0.15)		(0.36)	
Log Inv. IP-Ratio: $\ln(FG^i_{xt}/IM^i_{xjt})$	0.88***		1.95***	
	(0.30)		(0.70)	
Log IP-Ratio + Log FVA Ratio ($\gamma^{IP} + \gamma^{FVA}$)		0.63***		1.53***
		(0.22)		(0.50)
Reciprocal Trade Agreement: RTA_{ijt}	-4.59***	-4.50***	-7.19***	-7.13***
	(0.89)	(0.90)	(1.34)	(1.33)
Observations	8,707	8,707	7,643	6,229
R-Squared	0.520	0.536		

Column Fixed Effects				
Importer-Year	Y	N	Y	N
Industry-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: The regression specification is based on Equation (17). The dependent variable in all columns is the applied bilateral tariff of country i in industry x against exporter j at time t: t^i_{xjt}. Log DVA-Ratio ($\ln(DVA^j_{ijt}/IM^i_{xjt})$) is the ratio of domestic value added from the importing country (i) embodied in final production in industry x in the exporting country (j) to bilateral final goods imports for i from j in industry x. Log FVA-Ratio ($\ln(FVA^j_{xit}/IM^i_{xjt})$) is the ratio of foreign value added in final production in country i and industry x to bilateral final goods imports. Log IP-Ratio ($\ln(p^i_{xt}q^i_{xt}/IM^i_{xjt})$) is final production in country i and industry x to bilateral final goods imports. With importer-industry-year fixed effects, only the sum of the coefficients on the log FVA-Ratio and log IP-Ratio is identified. Reciprocal Trade Agreement (RTA_{ijt}) is an indicator that takes the value one if i and j have a RTA in force in year t. Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

Table 6: Bilateral Tariffs and Value Added Content Inside versus Outside RTAs

Panel A: Full Sample & Heteogeneous RTA Coefficients	OLS		Tobit	
	(1)	(2)	(3)	(4)
Log DVA-Ratio Outside RTA: $[1 - RTA_{ijt}] \times \ln(DVA^j_{xit}/IM^i_{xjt})$	-0.48***	-0.54***	-1.34***	-1.43***
	(0.18)	(0.20)	(0.42)	(0.45)
Log DVA-Ratio Inside RTA: $RTA_{ijt} \times \ln(DVA^j_{xit}/IM^i_{xjt})$	0.16	0.10	-0.23	-0.29
	(0.53)	(0.55)	(0.68)	(0.70)
Log FVA-Ratio Outside RTA: $[1 - RTA_{ijt}] \times \ln(FVA^i_{xt}/IM^i_{xjt})$	-0.17		0.025	
	(0.16)		(0.44)	
Log FVA-Ratio Inside RTA: $RTA_{ijt} \times \ln(FVA^i_{xt}/IM^i_{xjt})$	-2.87*		-5.38**	
	(1.49)		(2.38)	
Log Inv. IP-Ratio Outside RTA: $[1 - RTA_{ijt}] \times \ln(FG^i_{xt}/IM^i_{xjt})$	0.73***		1.39**	
	(0.28)		(0.67)	
Log Inv. IP-Ratio within RTA: $RTA_{ijt} \times \ln(FG^i_{xt}/IM^i_{xjt})$	3.16***		6.18***	
	(1.12)		(2.06)	
Log IP-Ratio + Log FVA-Ratio ($\gamma^{IP} + \gamma^{FVA}$)		0.62***		1.51***
		(0.22)		(0.48)
Log FVA-Ratio Inside RTA − Outside RTA		-2.74*		-5.24**
		(1.56)		(2.55)
Log IP-Ratio Inside RTA − Outside RTA		2.48**		4.58**
		(1.09)		(2.15)
Reciprocal Trade Agreement: RTA_{ijt}	-8.33***	-8.32***	-14.3***	-13.7***
	(1.95)	(2.03)	(4.15)	(4.13)
Observations	8,707	8,707	7,643	6,229
R-Squared	0.536	0.552		

Panel B: No RTA Sample	OLS		Tobit	
	(5)	(6)	(7)	(8)
Log DVA-Ratio: $\ln(DVA^j_{xit}/IM^i_{xjt})$	-0.12*	-0.15**	-0.49***	-0.52***
	(0.063)	(0.073)	(0.18)	(0.20)
Log FVA-Ratio: $\ln(FVA^i_{xt}/IM^i_{xjt})$	-0.054		0.11	
	(0.074)		(0.21)	
Log Inv. IP-Ratio: $\ln(FG^i_{xt}/IM^i_{xjt})$	0.28***		0.62**	
	(0.10)		(0.27)	
Log IP-Ratio + Log FVA-Ratio ($\gamma^{IP} + \gamma^{FVA}$)		0.26***		0.79***
		(0.078)		(0.23)
Observations	8,045	8,045	5,910	4,358
R-Squared	0.476	0.507		

Column Fixed Effects (both panels)				
Importer-Year	Y	N	Y	N
Industry-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: See Table 5 notes. Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

Table 7: Temporary Trade Barriers and Value Added Content

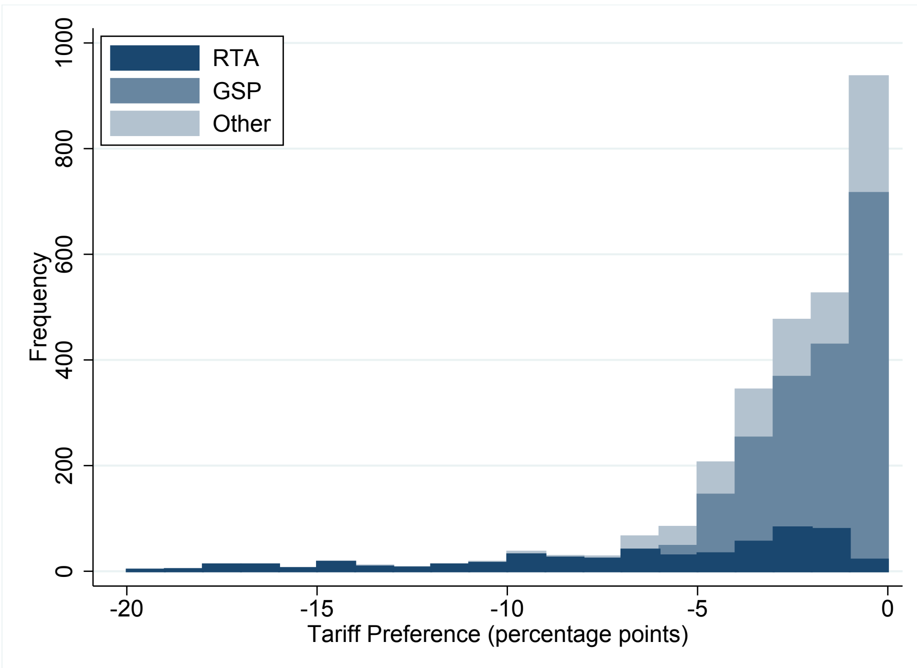
Panel A: Homogeneous Coefficients		
	(1)	(2)
Log DVA-Ratio: $\ln(DVA^{j}_{xi,t-5}/IM^{i}_{xj,t-5})$	-0.40***	-0.19***
	(0.079)	(0.065)
Log FVA-Ratio: $\ln(FVA^{i}_{x,t-5}/IM^{i}_{xj,t-5})$	-5.96***	
	(1.29)	
Log Inv. IP-Ratio: $\ln(FG^{i}_{x,t-5}/IM^{i}_{xj,t-5})$	6.29***	
	(1.31)	
Log IP-Ratio + Log FVA-Ratio ($\gamma^{IP} + \gamma^{FVA}$)		0.17***
		(0.063)
Reciprocal Trade Agreement: RTA_{ijt}	0.12	-0.056
	(0.13)	(0.080)
Observations	5,912	5,912
R-Squared	0.371	0.761

Panel B: Heterogeneous Coefficients for China as an Exporter		
	(3)	(4)
$\ln(DVA^{j}_{xi,t-5}/IM^{i}_{xj,t-5}) \times$ exporter = China	-1.27***	-0.62*
	(0.41)	(0.33)
$\ln(DVA^{j}_{xi,t-5}/IM^{i}_{xj,t-5}) \times$ exporter $\neq$ China	-0.27***	-0.16**
	(0.073)	(0.062)
$\ln(FVA^{i}_{x,t-5}/IM^{i}_{xj,t-5}) \times$ exporter = China	-5.16***	
	(1.37)	
$\ln(FVA^{i}_{x,t-5}/IM^{i}_{xj,t-5}) \times$ exporter $\neq$ China	-6.03***	
	(1.30)	
Log Inv. IP-Ratio: $\ln(FG^{i}_{x,t-5}/IM^{i}_{xj,t-5})$	6.24***	
	(1.31)	
Log IP-Ratio + Log FVA-Ratio ($\gamma^{IP} + \gamma^{FVA}$)		0.14**
		(0.057)
Reciprocal Trade Agreement: RTA_{ijt}	0.070	-0.053
	(0.14)	(0.079)
Observations	5,912	5,912
R-Squared	0.376	0.762

Column Fixed Effects (both panels)		
Importer-Year	Y	N
Industry-Year	Y	N
Importer-Industry	Y	N
Importer-Industry-Year	N	Y
Exporter-Industry-Year	Y	Y

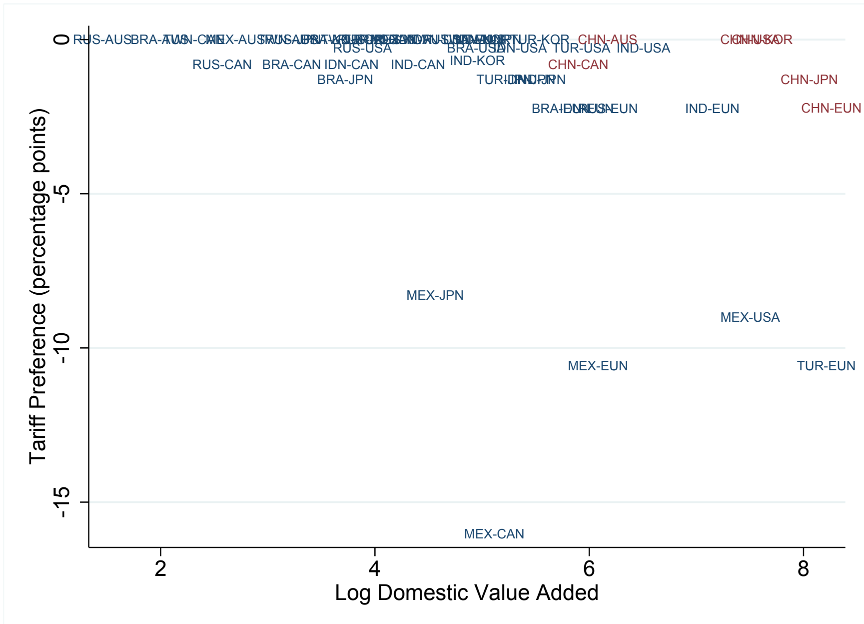
Note: Dependent variable in all columns is the temporary trade barrier coverage ratio for importer i against partner j for final goods imports in industry x: TTB^{i}_{xjt}. Log DVA-Ratio, FVA-Ratio, and Inv. IP-Ratios are lagged, one period back (five years), to reflect information available when TTBs were adopted. In Panel B, DVA and FVA are interacted with indicators for whether China is the exporting country. Standard errors (in parentheses) are clustered by importer-exporter-industry. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

Figure 1: The Distribution of Tariff Preferences

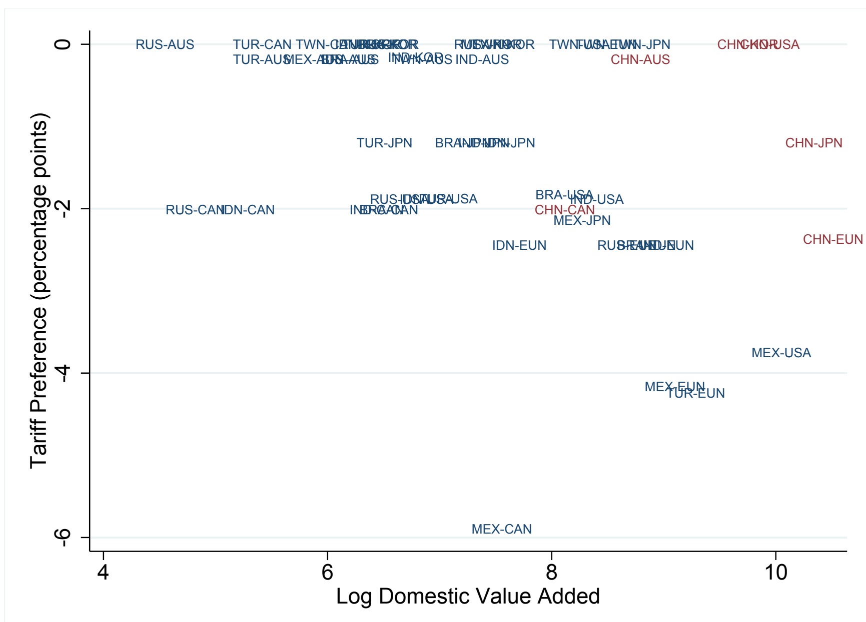


Note: Tariff preference equals the applied bilateral tariff for importer i against exporter j in industry x minus the MFN applied tariff for importer i in industry x. The histogram includes only observations for which applied bilateral tariffs are lower than MFN, and excludes 36 observations with preferences < -20 for legibility. The legend indicates the institutional source of preferences. RTA stands for bilateral or ”Regional Trade Agreement” and GSP stands for “Generalized System of Preferences.” Other includes partial scope agreements and miscellaneous preference schemes. Bin width is set to 1 percentage point.

Figure 2: Tariff Preferences and Domestic Value Added in Foreign Final Goods



(a) Textiles and Apparel



(b) All Manufacturing Industries

Note: Figure includes high-income importers and emerging economies exports in 2005. High-income countries include Australia, Canada, the European Union, South Korea, and the United States. Emerging economies include the other 9 countries listed in Table 1. Textiles and Apparel is WIOD sector 4, and All Manufacturing is WIOD sectors 4-16. Labels indicate exporter-importer pair.

A Theory Appendix

This appendix derives the optimal bilateral tariff when the quantities of value added used in each sector and destination are endogenous. While we use a specific-factors structure to streamline the derivation of the optimal tariff in the main text, we show here that the predictions we examine and the estimation framework we adopt are essentially the same in this more general setting. With the exception of those changes introduced below, all remaining assumptions are as in the main text.

In place of the specific-factors structure introduced in Section 1.2, we now assume that producers can adjust the quantity of value-added inputs used in production in response to value-added prices, subject to frictions. These frictions limit the substitutability of value-added inputs across end-use sectors or destinations, so that the equilibrium returns to value added may differ across countries and industries. Since the returns to value added depend in turn on final goods prices, the pattern of value added is a function of the complete vector of worldwide final goods prices; i.e. $\vec{\nu} \equiv \vec{\nu}(\vec{r}(\vec{p}; \vec{\nu})) \equiv \vec{\nu}(\vec{p})$. Likewise, we collapse the arguments for the returns to value added in terms of worldwide final goods prices: $\vec{r}(\vec{p}; \vec{\nu}(\vec{p})) \equiv \vec{r}(\vec{p})$.

As before, national income is given by the sum of final goods production (measured at local prices), tariff revenue, plus payments to domestic value added embodied in foreign production (DVA) and less payments to foreign value added used in local production (FVA):

$$I^i = 1 + \vec{p^i} \cdot \vec{q^i}(\vec{p}) + R(\vec{p}, I^i) + \underbrace{\sum_{s \in \mathcal{S}} \sum_{c \neq i \in \mathcal{C}} r^c_{si} \nu^c_{si}}_{\equiv DVA_i(\vec{p})} - \underbrace{\sum_{s \in \mathcal{S}} \sum_{c \neq i \in \mathcal{C}} r^i_{sc} \nu^i_{sc}}_{\equiv FVA^i(\vec{p})} . \tag{A1}$$

There are two key differences relative to the baseline version of the model. First, there is a second mechanism by which a tariff change affects the return to value added – in addition to altering the *prices* of value added, $\vec{r}$, changes in final goods prices can shift the equilibrium pattern of value added *quantities* used in production, $\vec{\nu}$. We will see these two effects as separate elasticities on the DVA and FVA terms in the optimal tariff expression below.

Second, with endogenous value added, all elements of domestic local production, FVA, and DVA now depend on the *complete* vector of world prices via $\vec{\nu}(\vec{p})$. Commensurately, a change in any given bilateral tariff (on a particular good from a particular country) may (potentially) disrupt the entire world vector of prices in all sectors, in every country.[63] These broader price transmission relationships complicate exposition, but they do not fundamentally alter the key mechanisms in which we are most interested. There are simply more potential indirect effects that operate through the endogenous reallocation of value added across other end-use sectors and 'third' countries (i.e. $s \neq x \in \mathcal{S}$ and $c \neq i, j \in \mathcal{C}$.).

We assume, like before, that the government maximizes the weighted sum of national income, consumer surplus, and individual producer influences. To simplify notation, we also now assume that the political welfare weights are the same across trading partners and

[63] For intuition, consider a unilateral increase in τ^i_{xj}. In the baseline model in the text, this would cause r^j_{xi} to fall, but ν^j_{xi} would remain fixed by assumption. With endogenous value added, the reduction in r^j_{xi} would cause value added to exit sector x in now-less-attractive country j, disrupting the worldwide pattern of value added content quantities, $\vec{\nu}$, and thus the equilibrium pattern of worldwide final goods production and prices.

sectors. The optimal tariff imposed by country i on a given final good $x \in \mathcal{S}$ imposed against country $j \neq i \in \mathcal{C}$ is then given by:

$$\tau^i_{xj} = \arg\max \quad I^i + \zeta(\vec{p^i}) + \delta^i \sum_s \pi^i_s(\vec{p}) - \delta^i_* FVA^i(\vec{p}) + \delta^*_i DVA_i(\vec{p})]. \qquad \text{(A2)}$$
$$\text{s.t.} \quad p^i_x = \tau^i_{xj} p^j_x \quad \text{and} \quad \tau^i_{xj} \leq \tau^{i,MFN}_x.$$

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

$$G_{\tau^i_{xj}} = \nabla I \cdot D_{\tau^i_{xj}} \vec{p} + \nabla \zeta \cdot D_{\tau^i_{xj}} \vec{p^i} + \delta^i \sum_s \frac{d\pi^i_s}{d\tau^i_{xj}} - \delta^i_* \frac{dFVA^i}{d\tau^i_{xj}} + \delta^*_i \frac{dDVA_i}{d\tau^i_{xj}} = 0. \qquad \text{(A3)}$$

In the first term, ∇I is the gradient of income with respect to the $(1 \times SC)$ world-price vector, $\vec{p}$, and $D_{\tau^i_{xj}} \vec{p}$ is the $(SC \times 1)$ derivative of the world price vector with respect to the bilateral tariff (so, $\nabla I \cdot D_{\tau^i_{xj}} \vec{p} = \frac{dI}{d\tau^i_{xj}}$). In the second term, the derivative of consumer surplus, ∇V is the $(1 \times S)$ gradient vector of indirect utility with respect to each of the S elements of the local price vector, $\vec{p^i}$, and $D_{\tau^i_{xj}} \vec{p^i}$ is the $(S \times 1)$ derivative of the local price vector with respect to the bilateral tariff. The last three terms are self-explanatory.

Using Roy's identity, collecting terms, and expanding the political economy and value added terms yields:

$$\begin{aligned} G_{\tau^i_{xj}} = \quad & \sum_s \sum_{c \neq i} \left[-M^i_{sc} \frac{dp^c_s}{d\tau^i_{xj}} + t^i_{sc} p^c_s \nabla M^i_{sc} \cdot D_{\tau^i_{xj}} \vec{p} \right] + \\ & + \delta^i \vec{q^i} \cdot D_{\tau^i_{xj}} \vec{p^i} + (1 + \delta^*_i) \underbrace{\nabla DVA_i \cdot D_{\tau^i_{xj}} \vec{p}}_{\equiv \frac{dDVA}{d\tau^i_{xj}}} - (1 - \delta^i_*) \underbrace{\nabla FVA^i \cdot D_{\tau^i_{xj}} \vec{p}}_{\equiv \frac{dFVA}{d\tau_{xj}}} = 0. \quad \text{(A4)} \end{aligned}$$

Above we use ∇M^i_{sc} to represent the gradient of bilateral imports of each good s from trading partner c to country i with respect to the complete world price vector, and ∇DVA_i and ∇FVA^i to represent respectively the gradients of country i's domestic value added embodied in foreign production, and foreign value added returns used in country i's production (again with respect to the world price vector).

Paralleling our earlier approach, we introduce the term Ω^{Ri}_{xj} to capture the (potential) effects on trade revenue collected on exports other than those in sector x from country j.[64] Dividing through by the bilateral trade volume and $\frac{dp^j_x}{d\tau^i_{xj}}$ yields the optimal tariff expression:

$$t^i_{xj} \tilde{\epsilon}^i_{xj} = 1 - \frac{\delta^i \vec{q^i} \cdot \vec{\Lambda}^i_{ixj}}{M^i_{xj}} - (1 + \delta^*_i) \frac{\nabla DVA_i \cdot \vec{\Lambda}_{ixj}}{M^i_{xj}} + (1 - \delta^i_*) \frac{\nabla FVA^i \cdot \vec{\Lambda}_{ixj}}{M^i_{xj}} - \tilde{\Omega}^{Ri}_{xj}, \qquad \text{(A5)}$$

where $\tilde{\epsilon}^i_{xj}$ is the general equilibrium analog to the bilateral export supply elasticity in the

[64] $\Omega^{Ri}_{xj} \equiv \sum_s \sum_{c \neq i,j} \left[-E^i_{sc} \frac{dp^c_s}{d\tau^i_{xj}} + t^i_{sc} p^c_s \nabla_{\vec{p}} E^i_{sc} \cdot D_{\tau^i_{xj}} \vec{p} \right] + \sum_{s \neq x} \left[-E^i_{sj} \frac{dp^j_s}{d\tau^i_{xj}} + t^i_{sj} p^j_s \nabla_{\vec{p}} E^i_{sj} \cdot D_{\tau^i_{xj}} \vec{p} \right].$

baseline version of the model and $\vec{\Lambda}_{ixj} \equiv \frac{D_\tau \vec{p}}{dp_x^j / d\tau_{xj}^i}$ is the $(SC \times 1)$ vector of the induced changes in the world price vector following a change in τ_{xj}^i, *relative* to the price change in the directly-affected sector x in country j.[65] Similarly, $\vec{\Lambda}_{ixj}^i \equiv \frac{D_\tau \vec{p}^i}{dp_x^j / d\tau_{xj}^i}$ is the $(S \times 1)$ vector of induced changes in the local (country i) prices *relative* to the change in p_x^j. Let $\tilde{\Omega}_{xj}^{Ri} \equiv \Omega_{xj}^{Ri} / (\frac{dp_x^j}{d\tau_{xj}^i} M_{xj}^i)$ again capture the tariff revenue effects of trade diversion in outside sectors and countries via changes in world price and the pattern of value added use.

Apart from the more complex general equilibrium price mappings, the basic form of the optimal tariff expression in (A5) is unchanged from the main text. As before, we can decompose the two value added terms into elasticities and empirically-measurable quantities of DVA and FVA. In the process, we also separate out the "direct" effect of the bilateral tariff change on the price of the target-good x in trading partners i and j apart from other indirect "general equilibrium" effects.

$$\begin{aligned}
\frac{\nabla DVA_i \cdot \vec{\Lambda}_{ixj}}{M_{xj}^i} &= \frac{1}{M_{xj}^i} \sum_s \sum_{c \neq i} (\nu_{si}^c \nabla r_{si}^c + r_{si}^c \nabla \nu_{si}^c) \cdot \vec{\Lambda}_{ixj} \\
&= \sum_s \sum_{c \neq i} \left(\frac{r_{si}^c \nu_{si}^c}{p_s^c M_{xj}^i} \right) \Bigg(\underbrace{\frac{p_x^j}{r_{si}^c} \nabla r_{si}^c \cdot \Lambda_{ixj}}_{\equiv \tilde{\varepsilon}_{si(ijx)}^{rc}} + \underbrace{\frac{p_x^j}{\nu_{si}^c} \nabla \nu_{si}^c \cdot \Lambda_{ixj}}_{\equiv \tilde{\varepsilon}_{si(ijx)}^{\nu c}} \Bigg) \\
&= \underbrace{\frac{r_{xi}^j \nu_{xi}^j}{p_x^j M_{xj}^i} (\tilde{\varepsilon}_{xi}^{rj} + \tilde{\varepsilon}_{xi}^{\nu j})}_{\text{direct effect}} + \underbrace{\sum_{c \neq i} \sum_{s \neq x} \frac{r_{si}^c \nu_{si}^c}{p_x^j M_{xj}^i} (\tilde{\varepsilon}_{si}^{rc} + \tilde{\varepsilon}_{si}^{\nu c}) + \sum_{c \neq i,j} \frac{r_{xi}^c \nu_{xi}^c}{p_x^j M_{xj}^i} (\tilde{\varepsilon}_{xi}^{rc} + \tilde{\varepsilon}_{xi}^{\nu c})}_{\text{indirect (GE) effects } \equiv \tilde{\Omega}_{xj}^{DVAi}} \\
&= (\varepsilon_{xi}^{rj} + \varepsilon_{xi}^{\nu j}) \frac{DVA_{xi}^j}{p_x^j M_{xj}^i} + \tilde{\Omega}_{xj}^{DVAi} \qquad \text{(A6)}
\end{aligned}$$

[65] Formally, $\tilde{\epsilon}_{xj}^i \equiv \frac{p_x^j}{E_{xi}^i} \frac{1}{\nabla_{\vec{p}} E_{xi}^j \cdot \vec{\Lambda}_{ixj}}$ is the bilateral export supply elasticity allowing the tariff change to work through the complete vector of final good prices (in addition to the foreign local price, p_x^j as is standard). Note that the elements of the $\vec{\Lambda}$ vector, which take the form of $\frac{dp_s^c}{d\tau} / \frac{dp_x^j}{d\tau}$, are the *inverse* of the $\lambda (\equiv \frac{dp^j}{d\tau} / \frac{dp_s^c}{d\tau})$ terms used in the main text (and in Bagwell and Staiger (1999)). We make this change both for notational convenience and because standard modeling assumptions render most elements of the numerator of our $\vec{\Lambda}$ vector zero (consistent with the absence of general equilibrium effects of a bilateral tariff change).

Following the same procedure for the FVA term:

$$\begin{aligned}
\frac{\nabla FVA^i \cdot \vec{\Lambda}_{ixj}}{M^i_{xj}} &= \sum_s \sum_{c\neq i} \left(\frac{r^i_{sc}\nu^i_{sc}}{p^j_x M^i_{xj}}\right)\left(\underbrace{\frac{p^j_x}{r^i_{sc}}\nabla r^i_{sc}\cdot\Lambda_{ixj}}_{\equiv\tilde{\varepsilon}^{ri}_{sc(ijx)}} + \underbrace{\frac{p^j_x}{\nu^i_{sc}}\nabla \nu^i_{sc}\cdot\Lambda_{ixj}}_{\equiv\tilde{\varepsilon}^{\nu i}_{sc(ijx)}}\right) \\
&= \underbrace{\sum_{c\neq i}\frac{r^i_{xc}\nu^i_{xc}}{p^j_x M^i_{xj}}(\tilde{\varepsilon}^{ri}_{xc}+\tilde{\varepsilon}^{\nu i}_{xc})}_{\text{direct effect}} + \underbrace{\sum_{c\neq i}\sum_{s\neq x}\frac{r^i_{sc}\nu^i_{sc}}{p^j_x M^i_{xj}}(\tilde{\varepsilon}^{ri}_{sc}+\tilde{\varepsilon}^{\nu i}_{sc})}_{\text{indirect effects }\equiv\tilde{\Omega}^{FVAi}_{xj}} \\
&= (\varepsilon^{ri}_{x*}+\varepsilon^{\nu i}_{x*})\frac{FVA^i_x}{p^i_x M^i_{xj}} + \tilde{\Omega}^{FVAi}_{xj}. \qquad \text{(A7)}
\end{aligned}$$

Finally, we also separate the political economy term into direct (sector x) and indirect (sectors $s \neq x \in \mathcal{S}$) components:

$$\frac{\delta^i \vec{q}^i \cdot \vec{\Lambda}^i_{ixj}}{M^i_{xj}} = \underbrace{-\frac{\delta^i q^i_x}{|\lambda^i_{xj}|M^i_{xj}}}_{\text{direct effect}} + \underbrace{\sum_{s\neq x}\frac{\delta^i q^i_s}{\lambda^i_{sj}M^i_{xj}}}_{\text{indirect effect}\equiv\tilde{\Omega}^{PEi}_{xj}}, \qquad \text{(A8)}$$

where $\lambda^i_{xj} \equiv \frac{dp^j_x}{d\tau^i_{xj}} / \frac{dp^i_x}{d\tau^i_{xj}} < 0$, as in the main text.[66]

Substituting the decompositions in (A6)-(A8) into the optimal tariff expression, we can rewrite the optimal bilateral tariff expression:

$$t^i_{xj} = \frac{1}{\tilde{\epsilon}^i_{xj}}\left(1 + \underbrace{\frac{\delta^i q^i_x}{|\lambda^i_{xj}|M^i_{xj}}}_{(+)} \underbrace{-(1+\delta^*_{xi})(\varepsilon^{rj}_{xi}+\varepsilon^{\nu j}_{xi})\frac{DVA^j_{xi}}{p^j_x M^i_{xj}}}_{(-)} + \underbrace{(1-\delta^i_{x*})(\varepsilon^{ri}_{x*}+\varepsilon^{\nu i}_{x*})\frac{FVA^i_x}{p^i_x M^i_{xj}}}_{(-)\text{ iff }\delta^i_{x*}<1} - \tilde{\Omega}^i_{xj}\right), \qquad \text{(A9)}$$

where $\tilde{\Omega}^i_{xj}$ captures all of the "indirect" effects of the tariff change on via country i's tariff revenue, domestic political economy and FVA in sectors other than x, as well as the DVA influences other sectors and in the returns to DVA in trading partners other than j.[67]

This optimal tariff expression is the general equilibrium analog to the specific factors version of the model presented in the main text.[68] Focusing on the direct bilateral, sector-x elements, we see that the optimal tariff is (again) inversely related to the bilateral trade elasticity, augmented by domestic political economy, DVA, and FVA motivations. The key difference is that the *quantitative* effects of DVA and FVA on the optimal tariff depend on the elasticity of both value added *prices* (via ε^r) and *quantities* (via ε^ν) with respect to tariff-induced price changes. Empirically, these two elasticities will be captured by our coefficient estimates, together with the political economy weights.

[66] Similarly, define $\lambda^i_{sj} \equiv \frac{dp^j_s}{d\tau^i_{xj}} / \frac{dp^i_s}{d\tau^i_{xj}}$ $\forall s \in \mathcal{S}$; the sign of λ^i_{sj} is ambiguous for $s \neq x$.

[67] $\tilde{\Omega}^i_{xj} \equiv \tilde{\Omega}^{Ri}_{xj} - \tilde{\Omega}^{FVAi}_{xj} + \tilde{\Omega}^{DVAi}_{xj} + \tilde{\Omega}^{PEi}_{xj}$.

[68] Most of the "nuisance" general equilibrium effects would arise in a broad class of GE frameworks, and are not about value-added components of trade, per se.

B Data Appendix

B.1 Computing Value Added Content

As noted in the text, our measures of domestic content in foreign production and foreign content in domestic production can be motivated as an application of the 'global value chain' decomposition of final goods developed in Los, Timmer and de Vries (2015).[69] We briefly describe the computation here.

As in the main text, let $i, j \in \{1, 2, \ldots, C\}$ denote countries and $s \in \{1, 2, \ldots, S\}$ denote industries. The World Input-Output Database includes an input shipments matrix, II_t, with $(S \times S)$ dimensional block elements $II_{ijt}(s, s')$ that record input shipments from sector s in country i to sector s' in country j. These matrices can easily be re-written in share form. Let A_{ijt} be a $(S \times S)$ dimensional 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 in sector s' in country j. Then assemble blocks A_{ijt} into the global input-output matrix A_t. The Leontief inverse of the global input-output matrix, $[I - A_t]^{-1}$, times any $(SC \times 1)$ vector of final goods output equals yields the $(SC \times 1)$ vector of gross output (from all countries and industries) required to produce those final goods.

Let f_{it} be the $(S \times 1)$ vector of final goods produced in country i, which are directly reported in the World Input-Output Database. Stack these into a $(SC \times 1)$ vector f_t, and compute $Y_t \equiv [I - A_t]^{-1} diag(f_t)$. Breaking this down, Y_t contains block elements Y_{ijt} which are $S \times S$ matrices describing output from country i used (directly or indirectly) to produce final goods in country j. Each sub-component $Y_{ijt}(s, s')$ is the amount 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 $x \in \mathcal{S}$ is: $VA^j_{xit} \equiv \sum_s R_{it}(s) Y_{ijt}(s, x)$. 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}) and foreign value added embodied in country i's domestic production of s (FVA^i_{st}). Specifically, for a given good x, $DVA^j_{xit} \equiv VA^j_{xit}$ and $FVA^i_{xt} \equiv \sum_{c \neq i \in \mathcal{C}} VA^i_{xct}$.

We compute value added content using the disaggregated 40 country version of the WIOD data set. We then aggregate value-added content across EU countries to form the EU composite, because EU countries have common external tariffs and trade policy.

[69] The global value chain traces backward through the production chain from final goods to identify the sources of value added in those goods. This is different than the value-added export decomposition developed by Johnson and Noguera (2012), which traces value added forward through the production chain to determine where value added from each country is ultimately consumed. It is also different than the decomposition of gross exports advanced by Koopman, Wang and Wei (2014).

B.2 Tariffs

B.2.1 Data Details

As noted in Section 3.2, we draw our data from UNCTAD (TRAINS) and the WTO via the WITS website. 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 four benchmark years. In most of these cases, 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. The following importing countries and years are excluded on these grounds: 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. We then classify these HS 6-digit categories into final versus intermediate use using BEC classifications as described in the text.

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.[70]

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.[71] Second, we retain

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

[71]To clarify, some importers may apply ad valorem tariffs in a given HS 6-digit sector, while others apply

only HS 6-digit categories for which we have a fully-balanced panel of tariffs — as in, for each importer, a given HS 6-digit tariff is observed for all partners in all years. This allows us to construct consistent tariff averages over time, as well as across partners at a given point in time.[72]

We aggregate these 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. We define a bilateral country pair to have a 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.

B.2.2 Sources of Tariff Preferences

As noted in the text, there are preferential tariffs in about a third of the importer-exporter-industry-year cells. The GSP program accounts for the majority (69 percent) of these preferences. In our data, there are three primary sources of time-varying discretion in the GSP program. The first is that each GSP granting country chooses the set of countries to which to grant GSP access. The second is that each GSP granting country chooses the set of industries covered by GSP, where industry exemptions apply to all GSP-partners. The third is that the importing country chooses the level of the GSP tariff to apply to its GSP-partners.[73] Each of these decisions is updated over time, as countries introduce or renew their GSP programs.[74] One important point is that the way GSP is recorded in our data understates the actual degree of discretion with which the GSP program is applied in practice.[75] As

specific duties in that sector. We only discard the HS sector for importers that actually apply specific duties, and retain the sector for other importers. Specific duties account for less than 2 percent of the HS 6-digit tariff lines for final goods. Discarding them avoids the well-understood concerns involved in converting specific tariffs to ad valorem equivalents, which are particularly problematic for aggregation or comparability across industries and countries.

[72]The cost of discarding unbalanced observations is that we lose about 13 percent of the (non-specific duty) importer-exporter-HS6-year tariff observations. We have confirmed that average bilateral industry-level tariffs computed from this balanced data are comparable to unbalanced averages that use all of the data. Further, tariff preferences (applied minus MFN tariffs) are nearly identical in balanced and unbalanced HS 6-digit tariff panels. Therefore, while this balancing step is useful for internal consistency, it is not important for the results.

[73]Regarding the second and third items, GSP preferences are reported at the HS 6-digit level in our data. As we aggregate, we take the simple average of GSP and MFN tariffs within each WIOD industry. Consequently, composite industry-level tariffs reflect both the set of HS 6-digit categories that receive tariff preferences as well as the size of those tariff preferences. In our data, GSP tariffs do not vary across the set of partners included in each importer's GSP program (with a few minor exceptions). In some industries, no HS 6-digit category receives preferences, in which case the entire industry is excluded from the GSP program.

[74]GSP preferences are identified by the "year" of the importer's GSP program in the raw tariff data.

[75]Specifically, importers deviate from the published GSP tariff schedule in our data for various (largely discretionary) reasons. For example, Blanchard and Hakobyan (2014) review the vagaries of country-product

such, our results regarding discriminatory preferential tariffs in the GSP program are likely conservative, since our data understates the true extent of discretion under GSP.

Bilateral trade agreements 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 so-called "Australia Tariff" in Canada's tariff schedule, under which Canada affords Australia preferential treatment for roughly 300 HS 6-digit categories.[76] Other idiosyncratic preference schemes are more limited, sometimes covering only a few miscellaneous HS 6-digit tariff lines.

Turning to bilateral trade agreements, we classify these preferences programs into two groups, consistent with our theoretical discussion in Section 1.4: *potentially* reciprocal trade agreements (RTAs) and non-reciprocal trade agreements.[77] Our baseline approach to classifying these agreements is as follows.

We define country i to have a potentially reciprocal trade agreement (RTA) with country j in year t if those countries have a trade agreement in force that was notified to the WTO under Article XXIV.[78] In the language of Article XXIV, these are commonly referred to as Customs Unions and Free Trade Areas. Article XXIV is a useful device to classify agreements because it requires countries to eliminate tariffs/duties on 'substantially all trade'. This requirement is evident in practice, as these agreements have much broader coverage on average than other trade agreements. Nonetheless, we repeat two points here that we emphasized in the main text. The first is that Article XXIV agreements still contain carve outs, which leave positive tariffs in many industries. The second is that some agreements in force have long, often highly asymmetric phase-in schedules.[79] These phase-in schedules are a source of discretion even inside reciprocal agreements. As a result of both of these sources of discretion, we treat these Article XXIV agreements as *potentially* reciprocal and test for the implications of reciprocity (i.e., that DVA should not influence tariffs inside RTAs).

We classify remaining trade agreements as non-reciprocal. These agreements are exclusively struck between developing countries, and most are notified to the WTO under the Enabling Clause.[80] Because they are notified under the Enabling Clause, these agreements

exclusions in the United States GSP program, including the discretionary application of "competitive needs limitations" and revocation of GSP privileges for violations of intellectual property and worker rights.

[76]Though a legacy of British colonial tariff preferences, this program was amended and re-authorized during our sample period, in 1998.

[77]A subtle note is that our language here differs a bit from the way the WTO describes these agreements. The WTO refers to all WTO-notified agreements as 'reciprocal' in that they involve the exchange of tariff preferences. We take 'reciprocal' to mean a sufficiently comprehensive and symmetric exchange of tariff preferences that nullifies bilateral terms-of-trade externalities within the agreement. There is not a strong presumption that terms-of-trade externalities are neutralized by partial agreements, covering a minority of trade. Whether agreements do achieve terms-of-trade neutralization is fundamentally an empirical question, which we address via our testing procedure.

[78]This definition identifies a set of reciprocal agreements among countries in our data that corresponds exactly to the set of FTAs and Customs Unions identified by Baier and Bergstrand (2007).

[79]A nice feature of our data is that we observe this phase-in process. For example, for the US-Australia free trade agreement, the United States implemented preferences immediately when the agreement entered into force, whereas Australia's implementation of preferences was more gradual. Similar issues arise for other agreements adopted within in our sample period (e.g., EU-Mexico, Japan-Mexico, etc.).

[80]One important agreement — a preferential agreement between Mexico and Brazil — has not been

are not bound by the 'substantially all trade' requirement of Article XXIV agreement. The data confirm that these agreements are much narrower in scope, having typical HS 6-digit coverage rates of less than 20 percent, compared to over 90 percent for RTAs. Reflecting this different standard, two of these agreements (the Asia-Pacific Trade Agreement and the Global System of Trade Preferences) are commonly referred to as "partial scope" agreements.

Table B1 lists the trade agreements in our data and our classification of them into reciprocal vs. non-reciprocal agreements. Because the division of agreements into reciprocal vs. non-reciprocal agreements is a subjective one, we also present an alternative broader classification in the table. Our broad RTA definition includes all Article XXIV agreements plus additional comprehensive agreements between developing countries. It is worth noting that these agreements are not necessarily free trade agreements, as commonly understood. For example, for the Brazil-Mexico agreement, the median tariff is 13 percent (the minimum is roughly 5.5 percent) at the industry level. While we focus on the definition of RTAs as WTO-notified Article XXIV agreements in our main results, we present supplemental results for the broad RTA classifications in Appendix C.

B.2.3 Another Look at MFN as a Constraint on Bilateral Applied Tariffs

An additional salient feature of the data is that tariff preferences are constrained by the MFN rule. When the MFN tariff is low, so too is the potential scope for tariff preferences, since tariffs are then bound between zero and the MFN rate. Given this, we would expect that both the absolute value of the mean preference and the standard deviation of preferences would be low when average MFN rates are also low. In Panel (a) of Figure B1, we see that preferences are indeed near zero when MFN tariffs are low (note the y-axis records negative values, since we define preferences as bilateral applied tariffs minus MFN tariffs). In Panel (b), we see that variability in preferences is rising with mean MFN tariffs. Both these patterns are consistent with MFN-censoring constraining variation in the data.

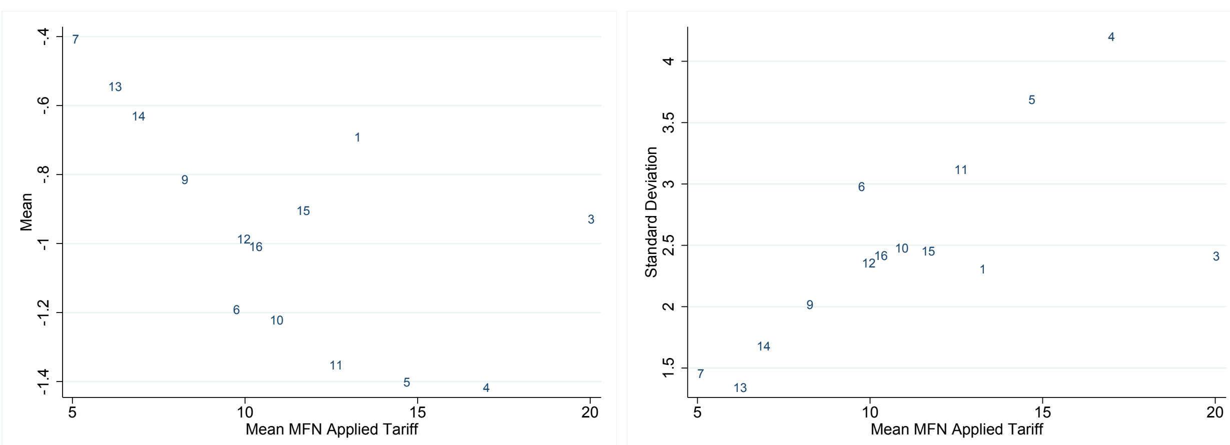
notified to the WTO, according to the WTO's trade agreement database [http://rtais.wto.org/UI/PublicMaintainRTAHome.aspx].

Table B1: Classifying Trade Agreements

	Years in Force	WTO Notification	RTA	Broad RTA
Bilateral Agreements				
Australia-United States	2005, 2009	Article XXIV	yes	yes
Brazil-Mexico	2005, 2009	None	no	yes
China-Indonesia (ASEAN)	2005, 2009	Enabling Clause	no	yes
European Union-Mexico	2000, 2005, 2009	Article XXIV	yes	yes
European Union-Turkey	2000, 2005, 2009	Article XXIV	yes	yes
Indonesia-South Korea	2009	Article XXIV	yes	yes
Japan-Indonesia	2009	Article XXIV	yes	yes
Japan-Mexico	2005, 2009	Article XXIV	yes	yes
Regional Agreements				
Asia-Pacific Trade Agreement	2005, 2009	Enabling Clause	no	no
Global System of Trade Preferences	1995, 2000, 2005, 2009	Enabling Clause	no	no
North American Free Trade Agreement	1995, 2000, 2005, 2009	Article XXIV	yes	yes

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.

Figure B1: Mean and Standard Deviation of Tariff Preferences versus MFN Tariffs, by Sector



(a) Mean of Tariff Preferences

(b) Standard Deviation of Tariff Preferences

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

C Supplemental Results

This appendix provides supplemental results. Section C.1 presents robustness checks related to estimation of Equation (14). Section C.2 presents instrumental variables estimates of Equation (17).

C.1 Robustness Checks for Domestic Value Added

In this section, we perform two checks on our baseline estimates.

First, we demonstrate that our main results regarding the role of domestic value added are robust to how we define reciprocal trade agreements. To so so, we replicate results from Tables 2 and 3 using a broader definition of RTAs. This broader definition, introduced in Appendix B [Section B.2.2 and Table B1], includes bilateral agreements adopted under Article XXIV plus comprehensive agreements not arising under Article XXIV.

In columns (1)-(3) of Table C1, we repeat the inside versus outside RTA analysis from Table 2. As before, the negative influence of DVA on tariffs manifests itself exclusively outside RTAs. Further, in columns (4) and (5), we show that the point estimate on DVA is negative in this alternative no-RTA sample, comparable in size to the main point estimates. We conclude that the exact definition of RTAs has little bearing on our analysis. Nonetheless, we retain non-Article XXIV agreements in our baseline no-RTA sample throughout the paper, because adoption of these is itself a manifestation of discretionary trade policy.

Second, we show that our baseline DVA results are robust to adding bilateral controls to proxy for potential omitted confounding variables. The first control we add is log bilateral final goods imports. In column (2) of Table C2, the coefficient on exports is significant, but the point estimate on log DVA is unchanged relative to the baseline. This implies that imports are essentially orthogonal to log DVA, given the controls. This is sensible, since we have already removed a substantial component of import variation by interacting import decile indicators with the importer-industry-year fixed effects.

The second set of controls are measures of bilateral characteristics (often used as proxies for trade costs in the gravity literature), including distance, colonial linkages, common language, and contiguity (common border).[81] We do this to rule out that omitted variables (either the proxies themselves, or variables that are correlated with the proxies) spuriously drive our results.

In Table C2, columns (3)-(6) report OLS estimates and columns (7)-(10) report IV estimates with DVA-in-Services as the instrument. As is evident, the coefficient on log DVA remains negative and significant after adding these controls, while the proxy variables themselves are almost never significant.

[81] We obtain these variables from the CEPII GeoDistance Database: http://www.cepii.org/CEPII/fr/bdd_modele/presentation.asp?id=6. One complication is that these characteristics pertain to individual bilateral country pairs, but we have a composite non-country entity (the EU) in our data. We therefore define bilateral characteristics vis-a-vis the EU by taking GDP-weighted averages of bilateral characteristics defined for each individual EU country. This implies that colonial linkages, common language, and contiguity are not strict indicator variables, as their weighted averages can lie between zero and one when the EU is a trading partner.

One point of interpretation is worth emphasizing here. The gravity variables could influence DVA in two ways. First, they could have a direct effect, either because they influence tariffs for various unmodeled reasons, or because they proxy for omitted determinants of tariffs. Second, they could have an indirect effect, via DVA. That is, DVA^j_{xi} is high when i supplies inputs to j, and input sourcing is naturally correlated with trade costs. The reason to point this out is that this likely explains why the DVA falls slightly when we add these controls. By adding them, we are mechanically removing some of the meaningful variation in DVA that drives tariffs and therefore diminishing its direct effect. Given this interpretation concern, as well as the insignificant point estimates on the proxies, we omit them in the remaining analysis in the main text.

C.2 Identifying the Influence of Foreign Value Added via Instrumental Variables

In Table 5, we presented OLS estimates of Equation (17), with two alternative sets of fixed effects. We noted that while one might be concerned about the endogeneity of foreign value added with respect to tariffs, this should bias the coefficient upward (i.e., toward zero/positive values, given that the point estimate is negative). In this sense, the OLS estimate of the FVA effect may be conservative. Further, we noted there that IV estimates in that specification tend to support this interpretation. We present the details of that argument here.

To instrument Equation (17), we require instruments for DVA^j_{xit}, FVA^i_{xt}, FG^i_{xt}, and IM^i_{xjt}. Needless to say, finding four instruments is a formidable challenge.[82] For DVA^j_{xit}, we use the DVA-in-Services instrument presented previously in Section 4.1. We construct three additional instruments for FVA^i_{xt}, FG^i_{xt}, and IM^i_{xjt} as follows.

Instrument for FG The instrument for final goods production is based on predicting final goods production for industry x in country i by taking a weighted average of total final expenditure in destinations j to which i sold output in a base period. Let FG^i_{xjt} be the value of final goods shipments from country i to j in industry x at date t. Letting 0 denote a base period, then total final goods production at date t can be written as:

$$FG^i_{xt} = FG^i_{x0} \sum_j \left(\frac{FG^i_{xj0}}{FG^i_{x0}} \right) \left[\frac{FG^i_{xjt}}{FG^i_{xj0}} \frac{FG_{xj0}}{FG_{xjt}} \right] \left(\frac{FG_{xjt}}{FG_{xj0}} \right), \tag{C1}$$

where FG_{xjt} is total final expenditure on industry x in destination j. The first term records the shares of final goods production sold to each destination in the base period. The middle term in square brackets records changes in final goods expenditure shares. The third term records changes in final expenditure levels. For the purposes of constructing an instrument,

[82]This particularly challenging in our context for two reasons. First, the fixed effects structure we adopt rules out many possible country, industry, or even country-industry instruments. Second, the potentially endogenous explanatory variables are correlated among themselves for structural reasons (e.g., FVA^i_{xt} depends on the level of FG^i_{xt}), and so many instruments for them are also correlated among themselves. As a result, many potential instruments suffer from weak instrument problems. We explicitly address weak instrument concerns below.

suppose that final goods import shares are constant over time, so that $\frac{FG^i_{xjt}}{FG^i_{xj0}}\frac{FG_{xj0}}{FG_{xjt}} = 1$. And then re-write the expression in logs:

$$\ln\left(FG^i_{xt}\right) \approx \ln\left(FG^i_{x0}\right) + \ln\left(\sum_j \left(\frac{FG^i_{xj0}}{FG^i_{x0}}\right)\frac{FG_{xjt}}{FG_{xj0}}\right). \tag{C2}$$

Because we include importer-industry fixed effects in all specifications, final goods production in the base year ($\ln(FG^i_{x0})$) is redundant. For identification, we rely solely on time variation in final goods production at the importer-industry level (with importer-specific and industry-specific effects differenced out), for which the second term is an instrument. Put differently, what we actually need is an instrument for growth in final goods production, and our instrument aggregates growth rates in destination expenditure using weights that depend on sales shares in the benchmark year. In constructing the instrument, we treat 1995 as the benchmark year.

Instrument for FVA The instrument for foreign value added in domestic production based on predicting how much foreign value added in used by industry x in country i using information on the foreign supply of value added in upstream industries. Intuitively, if foreign supply capacity grows quickly, then we expect the amount of foreign value added used in domestic production to rise. To capture this idea, we build an instrument as follows.

Let $FVA^i_{jt}(s,x)$ be the value added from country j and industry s used by industry x country i in production of final goods at date t. Again letting 0 denote a base period, FVA^i_{xt} can be written as:

$$FVA^i_{xt} = FVA^i_{x0}\sum_{j\neq i}\sum_s\left[\left(\frac{FVA^i_{jt}(s,x)}{FVA^i_{x0}}\right)\left(\frac{FVA^i_{jt}(s,x)}{FVA^i_{j0}(s,x)}\frac{VA^j_{s0}}{VA^j_{st}}\right)\left(\frac{VA^j_{st}}{VA^j_{s0}}\right)\right], \tag{C3}$$

where VA^j_{st} is total value added added in sector s of country j at date t. Similar to above, suppose that the value-added export shares are constant over time, so $\frac{FVA^i_{jt}(s,x)}{FVA^i_{j0}(s,x)}\frac{VA^j_{s0}}{VA^j_{st}} = 1$, and re-write the expression in logs:

$$\ln\left(FVA^i_{xt}\right) \approx \ln\left(FVA^i_{x0}\right) + \ln\left(\sum_{j\neq i}\sum_s\left(\frac{FVA^i_{jt}(s,x)}{FVA^i_{x0}}\right)\frac{VA^j_{st}}{VA^j_{s0}}\right). \tag{C4}$$

As above, the base year level of foreign value added ($\ln(FVA^i_{x0})$) will be absorbed by our fixed effects. The second term is then an instrument for growth in foreign value added used in domestic production over time. We again treat 1995 as the benchmark year in constructing the instrument.

Instrument for Final Goods Imports To instrument for final goods imports, we measure bilateral final goods imports at the industry level in 1970, prior to the introduction of the tariff preferences observed in our data. We use bilateral trade data at the SITC 4-digit (Rev. 2) level from the NBER-United Nations Trade Data [Feenstra et al. (2005)]. We extract SITC categories corresponding to final goods using the BEC classification, and then concord SITC categories to our WIOD industries via ISIC industries.[83]

Estimation and Results Using these instruments, we re-estimate the linear specifications in Table 5 and present the results in Table C3, along with the baseline OLS estimates from Table 5 for reference. In Columns (1) and (3), we instrument for the three ratios on the right hand side of Equation 17 by constructing the ratio of the instruments for the numerator in each ratio to the instrument for final goods imports.[84] In columns (2) and (4), we do the same for DVA and instrument for final goods imports to identify $\gamma^{IP} + \gamma^{FVA}$.

In Panel A, IV estimates are negative for domestic value added, negative for foreign value added, and positive for final goods production. These are consistent with the OLS sign estimates. In terms of magnitudes, the IV point estimates tend to move away from zero relative to OLS. That said, the 2SLS point estimates are substantially less precise than OLS. Nonetheless, one can reject the null that the import penetration and FVA ratios are exogenous in a Durbin-Wu-Hausman endogeneity test.[85]

In Panel B, we replicate the IV estimates for the sample excluding RTAs. The IV estimates here also broadly confirm the OLS estimates, though the details are more nuanced. The point estimate on DVA doesn't move between the OLS and IV estimates, but becomes insignificantly different than zero in the IV estimation due to the loss of precision. We cannot reject that DVA is exogenous in a Durbin-Wu-Hausman endogeneity test. Given our prior results concerning the role of DVA – both in Panel A and in previous IV-specifications, we see no reason to change our views on the sign of the DVA effect based on these results. Turning to FVA, the coefficient on FVA becomes negative and significant when we instrument here. This brings the FVA results in this sub-sample more in line with the full sample, including RTAs. Further, we can easily reject exogeneity of the FVA-Ratio here.

Together with our previous IV results, these results corroborate our interpretation of the OLS estimates as indicative of causal relationships. In particular, the new concern in this specification concerns the role of FVA. Recalling that the principal endogeneity concern is that tariffs raise FVA and thus bias the the FVA coefficient upward (toward zero/positive values), we argued in the text that our OLS estimates likely understate FVA effects. The IV results are broadly consistent with this interpretation. That said, we are reluctant to take the magnitude of the FVA estimate too seriously here due to the wide confidence interval.

One final point to note is that we report two-stage least squares standard errors (clustered by importer-exporter pair) in the table. The appropriateness 2SLS standard errors is not obvious: the high correlations among endogenous variables and therefore the instruments we use for them could give rise to weak instrument problems. Therefore, in the table, we report various weak-IV statistics to gauge the reasonableness of the 2SLS standard errors.

[83]Because country definitions have changed over time, we concord historical countries to modern entities as best we can. For example, Germany today corresponds most closely to the former Federal Republic of Germany. Russia today corresponds to the former USSR. And so on. Further, more trade flows in the NBER-UN data are zero in 1970 than are zero today, likely due both to true changes from zeros to positive values over time and differences in reporting thresholds and/or missing data in the two data sources. In order to use the whole sample, we replace zeros in 1970 with the smallest values observed in the data.

[84]Including the instruments separately, without imposing this ratio restriction, yields similar results.

[85]Testing the exogeneity of the DVA-Ratio alone, one cannot reject exogeneity.

We report statistics that allow for clustering – including tests for under-identification and weak identification [Kleinbergen and Paap (2006)] and conditional first-stage F statistics [Sanderson and Windmeijer (2015)]. These statistics suggest that that 2SLS standard errors are acceptable.[86] Nonetheless, we also computed Anderson-Rubin style confidence intervals that are robust to weak identification. These are comparable to the 2SLS confidence intervals and do not alter inference in any important way.

[86] In interpreting these statistics, an unfortunate fact is that there is little guidance about what the values of these cluster-robust statistics need to be to be on safe ground. Values of 10 or above for the conditional F statistics are typically thought to be safe. The rK statistics compare reasonably favorably to critical values developed for homoskedastic models.

Table C1: Bilateral Tariffs and Domestic Value Added in Foreign Production with Broad Definition of RTAs

	Full Sample			No RTA	No RTA Linear IV
	(1)	(2)	(3)	(4)	(5)
Log DVA: $\ln(DVA^{j}_{xit})$	-0.43**			-0.11*	-0.14***
	(0.17)			(0.062)	(0.049)
Log DVA Outside RTAs: $[1-RTA_{ijt}]\times\ln(DVA^{j}_{xit})$		-0.49**	-0.50*		
		(0.20)	(0.29)		
Log DVA Inside RTAs: $RTA_{ijt}\times\ln(DVA^{j}_{xit})$		0.030			
		(0.30)			
Reciprocal Trade Agreement: RTA_{ijt}	-3.73***	-6.26**	-6.17***		
	(0.65)	(2.47)	(1.76)		
Observations	8,853	8,853	8,853	8,076	8,076
R-Squared	0.991	0.991	0.991	0.998	0.998

Note: Dependent variable in all columns is the applied bilateral tariff of country i in industry x against exporter j at time t: t^{i}_{xjt}. Log DVA ($\ln(DVA^{j}_{ijt})$) is domestic value added from the importing country(i) embodied in final production in industry x in the exporting country (j). Reciprocal Trade Agreement is an indicator that takes the value one if i and j have a reciprocal trade agreement in force, according to the broad definition in Table B1. Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

Table C2: Bilateral Tariffs and Domestic Value Added in Foreign Production with Imports and Gravity Controls

	OLS		OLS with Gravity Proxies				Linear IV with Gravity Proxies: DVA-in-Services			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Log DVA: $\ln(DVA^j_{xit})$	-0.17**	-0.15**	-0.12*	-0.17**	-0.11*	-0.099	-0.16***	-0.21***	-0.16***	-0.13**
	(0.068)	(0.073)	(0.063)	(0.068)	(0.064)	(0.065)	(0.058)	(0.053)	(0.059)	(0.060)
Log Bilateral FG Imports: $\ln(IM^i_{xjt})$		-0.091**								
		(0.045)								
Log Bilateral Distance			0.12		0.15	0.16	0.090		0.12	0.13
			(0.12)		(0.14)	(0.14)	(0.082)		(0.094)	(0.097)
Colony				0.021	0.18	0.19		0.045	0.17	0.18
				(0.25)	(0.30)	(0.31)		(0.16)	(0.19)	(0.19)
Common Language						-0.24				-0.24*
						(0.23)				(0.14)
Contiguity						0.33				0.32
						(0.38)				(0.24)
Observations	8,187	8,104	8,187	8,187	8,187	8,187	8,187	8,187	8,187	8,187
R-Squared	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997

Note: Dependent variable in all columns is the applied bilateral tariff of country i in industry x against exporter j at time t: t^i_{xjt}. Log DVA ($\ln(DVA^j_{ijt})$) is domestic value added from the importing country(i) embodied in final production in industry x in the exporting country (j). The sample includes only country pairs without a reciprocal trade agreement in force. Bilateral distance, colony, language, and contiguity data from CEPII and aggregated using country-GDP weights for trade with the EU. Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.

Table C3: Instrumental Variables Estimates for Bilateral Tariffs and Value-Added Content

Panel A: Full Sample	Baseline OLS		Linear IV	
	(1)	(2)	(3)	(4)
Log DVA-Ratio: $\ln(DVA^{j}_{xi,t}/IM^{i}_{xj,t})$	-0.48***	-0.55***	-0.97**	-0.96**
	(0.18)	(0.21)	(0.40)	(0.40)
Log FVA-Ratio: $\ln(FVA^{i}_{x,t}/IM^{i}_{xj,t})$	-0.31**		-18.5**	
	(0.15)		(7.45)	
Log Inv. IP-Ratio: $\ln(FG^{i}_{x,t}/IM^{i}_{xj,t})$	0.88***		19.2**	
	(0.30)		(7.67)	
Log IP-Ratio + Log FVA Ratio ($\gamma^{IP} + \gamma^{FVA}$)		0.63***		0.68***
		(0.22)		(0.24)
Reciprocal Trade Agreement: RTA_{ijt}	-4.59***	-4.50***	-4.59***	-4.59***
	(0.89)	(0.90)	(0.85)	(0.85)
Observations	8,707	8,707	8,707	8,707
Under-Identfication Test (rk LM statistic)			33.7	21.3
Weak-Identfication Test (Wald rk F statistic)			13.3	12.0
Conditional F-Stat (Log DVA-Ratio)			25.65	24.26
Conditional F-Stat (Log FVA-Ratio)			53.53	
Conditional F-Stat (Log FG-Ratio)			53.52	

Panel B: No RTA Sample	Baseline OLS		Linear IV	
	(5)	(6)	(7)	(8)
Log DVA-Ratio: $\ln(DVA^{j}_{xi,t}/IM^{i}_{xj,t})$	-0.12*	-0.15**	-0.14	-0.13
	(0.063)	(0.073)	(0.25)	(0.25)
Log FVA-Ratio: $\ln(FVA^{i}_{x,t}/IM^{i}_{xj,t})$	-0.054		-6.36**	
	(0.074)		(3.21)	
Log Inv. IP-Ratio: $\ln(FG^{i}_{x,t}/IM^{i}_{xj,t})$	0.28***		6.65**	
	(0.10)		(3.26)	
Log IP-Ratio + Log FVA Ratio ($\gamma^{IP} + \gamma^{FVA}$)		0.26***		0.29***
		(0.078)		(0.078)
Observations	8,045	8,045	8,045	8,045
Under-Identfication Test (rk LM statistic)			27.6	17.3
Weak-Identfication Test (Wald rk F statistic)			10.5	9.60
Conditional F-Stat (Log DVA-Ratio)			19.81	19.48
Conditional F-Stat (Log FVA-Ratio)			37.88	
Conditional F-Stat (Log FG-Ratio)			37.83	

Fixed Effects (both panels)				
Importer-Year	Y	N	Y	N
Industry-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: See Table 5 notes. Under/Weak-Identification Tests are based on Kleinbergen and Paap (2006). Conditional F-Stats are based on Sanderson and Windmeijer (2015). Standard errors (in parentheses) are clustered by importer-exporter pair. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$.