Trade Elasticities, Heterogeneity, and Optimal Tariffs

Anson Soderbery*
Purdue University

February 6, 2017

Abstract

We develop a structural estimator for heterogenous supply and demand in the absence of instrumental variables. Using only readily available bilateral trade data we show how to leverage variation in prices and quantities across multiple markets in order to consistently estimate heterogeneous elasticities. Our elasticity estimates follow intuitive patterns of importer and exporter market power and produce believable distributions and magnitudes. To highlight the flexibility of the estimator, we extend the cornerstone theories of non-cooperative optimal trade policy to a setting where exporters have heterogeneous supply elasticities. Applying our estimates to trade and tariff data worldwide, we show that heterogeneous export supply elasticities provide new avenues for identification. We demonstrate strong and persistent links between optimal tariffs and applied tariffs worldwide that previous studies are unable to capture.

Keyword: Export supply, Import demand, Trade, Structural estimation, Optimal tariffs
JEL Classification: F12, F14, F59, C13

*This paper has benefitted immensely from discussions with Bruce Blonigen, Matilde Bombardini, Rob Feenstra, David Hummels, Nuno Limão, Nick Sly, Alan Spearot and Bob Staiger. I am additionally grateful to seminar participants at the SITE: International Trade Workshop, Empirical Investigations of International Trade, McMaster University, and Purdue University. Invaluable research assistance was provided by Marcelo Castillo. All errors and omissions are my own.

1 Introduction

At the root of empirical analysis of product markets are estimates of supply and demand elasticities. Here we develop a structural estimator of demand and supply that does not rely on instrumental variables and can identify variety by market specific heterogeneity in the elasticities. The estimator yields consistent estimates by leveraging variation in prices and quantities over time when products are sold in multiple markets.

These innovations are particularly important in the context of international trade where empirical analysis has a keen focus on the trade elasticities underlying our theoretical models. Trade economists generally observe many heterogeneous exporters selling varieties of many goods to multiple importers. The breadth of trade data thus implies estimating millions of elasticities across thousands of product markets worldwide. Consequently, constructing believable instruments for each market is a significant obstacle.

International trade, however, is particularly salient for the identification strategy of our estimator, as even publicly available data record countries exporting to and importing from many sources. We will show how price and quantity variation over time for the same good across export and import markets can be exploited to identify importer by exporter by product elasticities (i.e., heterogenous elasticities). We thus develop a tractable model of international trade that follows the common assumptions from new trade theory.[1] Structurally estimating the model yields the first consistent estimates of heterogeneous export supply and import demand elasticities for every country pair and good traded worldwide.[2]

Applying the structural estimator to the universe of trade flows at the HS4 level from (publicly available) Comtrade data uncovers significant heterogeneity in export supply elasticities even at the most disaggregate level – across imported varieties of a particular good. Evaluating the "reasonableness" of our elasticity estimates exploits the heterogeneity of the

[1]Specifically, demand will follow from constant elasticity of substitution preferences and exporters will have heterogenous upward sloping supply curves to every destination market.

[2]The key for the estimator is defining multiple markets with heteroskedastic differences in a time series of prices and quantities. While trade provides the perfect environment for defining multiple markets for a product (i.e., export and import flows), the methodology developed here could be more generally applied to any industry where the goal is to consistently estimate supply and demand elasticities simultaneously in the absence of believable instruments.

estimates and the interpretation of the inverse export supply elasticity as a measure of importer market power. We first establish intuitive relationships between product differentiation and market power. Importers are expected to possess more market power (i.e., large inverse export supply elasticities) for highly differentiated goods on average.[3] Our estimates confirm the intuition, and yield inverse export supply elasticities for differentiated goods that are around three times larger than for homogenous goods, on average. Additionally, we expect differentiated goods to be less substitutable than homogeneous goods. We confirm this expectation as our estimated import demand elasticities are on average eight percent larger for homogeneous than differentiated goods.

Importers could also have varying degrees of market power across types of goods depending on the composition of their imports. To investigate, we regress our inverse export supply elasticities on importer by product differentiation fixed effects. The estimated fixed effects allow us to rank the median market power across importer good pairs. As we might expect, the largest importers in the data (Germany, US and China) possess the highest degree of market power across the goods they import, while the smaller less developed importers (Brazil and Caribbean and African Countries) have the least market power.

Notably, these market power rankings vary across types of goods. China for instance ranks first in market power across differentiated goods, but near last for non-differentiated goods. China is notably reliant on distant foreign suppliers of raw materials, supporting the result that they possess relatively weak market power over non-differentiated goods.[4] Conversely, India ranks near last in differentiated goods, but third in market power for non-differentiated goods. India's imports of non-differentiated goods are predominantly supplied by regional trade partners, of which India is an important export destination. Our estimates thus support the idea that market power varies across types of goods and the composition of imports. These rich patterns suggest that heterogeneity in trade elasticities is important

[3]Intuitively, if US demand for say German microscopes falls and Germany decreases prices globally, there will be relatively weak substitution by other countries toward German microscopes due to the differentiated nature of this industry. The equilibrium world price for German microscopes may fall substantially in response to the shock in the US market, which is our definition of importer market power.

[4]A similar pattern also holds for other Asian countries, including Taiwan and Korea, even though they have lower market power across all of their imports relative to China.

for understanding patterns of market power, and by association, the motives for tariffs set by importers.

We demonstrate the importance of our estimates by adapting the model to advance the optimal non-cooperative trade policy literature to allow for exporter supply heterogeneity. To be clear, we model importers setting tariffs taking into account exporter heterogeneity to maximize welfare without internalizing potential foreign retaliation.[5] We employ our estimates to evaluate the model's efficacy in explaining applied tariffs worldwide from 1991-2007. Our estimates are shown to provide new insights into how trade policy is set.

Previous studies of optimal non-cooperative trade policy have assumed that every exporter of a particular good into a given destination exports under an *identical* supply elasticity. This assumption implies the optimal tariff that balances terms of trade gains and efficiency losses is the inverse of this common export supply elasticity. However, the significant heterogeneity uncovered by our estimates calls into question these simplifying assumptions. Intuitively, we are relaxing the assumption that, for instance, exported automobiles from Sweden to the US have the same export supply elasticity as automobiles originating from Japan.[6] Our estimated export supply elasticities capture such things as differences in the production processes associated with these two varieties and the degree of market power that the US has for each variety. Both of these channels translate into substantial differences in

[5] Ossa (2014) argues that WTO member countries should not be expected to set non-cooperative optimal tariffs given the cooperative nature of the WTO. He then contrasts the tariffs predicted by non-cooperative and cooperative optimal policies by simulating his model given moments in the data. Our optimal tariffs are derived in a non-cooperative setting, and estimated to be of similar magnitude to Ossa (2014)'s non-cooperative tariff estimates. Our exercise is then to investigate whether countries (including WTO members) tend to set non-cooperative tariffs even when we expect a cooperative equilibrium. Our estimates demonstrate that applied tariffs in the data strongly follow our predicted non-cooperative optimal tariffs worldwide.

[6] Using Comtrade data, HS code 8703 represents automobiles. Both Japanese and Swedish exporters are reliant on the US market – 23% of all Swedish and 44% of all Japanese auto exports were destined for the US in 2006. The key difference between the two is Swedish exports comprise only 1.4% of the US market, while Japanese exports capture 31.8%. This disparity suggests that the US might have a higher degree of market power over Japanese autos (i.e., face a larger inverse export supply elasticity), as prices of Japanese auto exports globally are more likely to be affected by shocks in the US market. We estimate an inverse export supply elasticity of 1.79 for Swedish exports to the US and 147.67 for Japanese exports, suggesting stronger US market power over Japanese exports. Notably, the pattern is the reverse when we consider Swedish versus Japanese exports of the same good to the UK. The UK is a more vital destination for Sweden – 13% of Swedish versus 2% of Japanese exports are destined for the UK. We estimate an inverse elasticity of 1.71 for Sweden, which compared to our estimate of 0.92 for Japan, suggesting greater market power for the UK over Swedish auto imports.

export supply elasticities for importer exporter pairs both within and across traded goods, which has significant implications for our understanding of optimal trade policy.

With heterogeneity in export supply elasticities, we show that the optimal non-cooperative tariff set by an importer is no longer the inverse of a single elasticity. When varieties of a good are exported from countries with heterogeneous export supply elasticities, we demonstrate that the optimal non-cooperative tariff weights the relative contribution of each variety to terms of trade gains and efficiency losses resulting from the tariff.[7]

We employ our model and estimates to compare theoretically optimal non-cooperative trade policy under heterogeneity with applied tariffs in the data. Now that the terms of trade (i.e., importer market power) motives for optimal tariffs under heterogeneity theoretically depend on the composition of exporters that make up an importer's trade, exporter heterogeneity introduces a new channel whereby optimal tariffs respond to compositional changes in trade over time. This new source of variation in optimal tariffs is used to demonstrate a much stronger connection between applied and optimal tariffs in the data than has been found in previous studies.

Notably, we are able to reconcile key features of the data that have been at odds with empirical analyses of optimal trade policy. For example, developed countries tend to have high estimated market power yet set low tariffs. Our introduction of exporter heterogeneity yields optimal tariffs that depend not only on estimates of importer market power but also on the composition of a countries imports. In the data, our estimates do in fact suggest high degrees of market power but low predicted optimal tariffs for developed countries. Additionally, our estimates are also able to demonstrate that importers in seemingly cooperative settings (e.g., WTO members) still set tariffs that target terms of trade motives (i.e., importer market power). This result is a direct consequence of allowing for heterogeneity,

[7] In essence, when the importer applies an identical tariff across multiple exporters with different export supply elasticities, each exporter yields a different terms of trade gain relative to its efficiency loss. The optimal tariff therefore chooses a tariff that optimally weights each exporter's contribution to its total terms of trade gains and efficiency losses. We focus on the case where an importer does not perfectly discriminate tariffs across each variety. The data support this assumption as importers commonly set an identical tariff for multiple exporters of the same good (e.g., MFN tariffs by WTO members). It can be shown that if an importer perfectly discriminates tariffs across all exporters of a particular good, the non-cooperative optimal tariff is the inverse of each exporter's supply elasticity. However, we never see perfect discrimination in tariff rates in our sample.

as importers' terms of trade motives depend on the composition of trade. This feature of our model lets us utilize time series variation to show that as countries join the WTO they restructure tariffs in a way that still targets terms of trade motives as the makeup of their trade relationships adjust with the new policies.

This paper proceeds as follows. Section 2 develops our quantitative model of trade that we structurally estimate in Section 3. Section 4 evaluates the patterns of the resulting estimates of heterogeneous supply and demand elasticities. Section 5.1 adapts the prevailing model of optimal non-cooperative trade policy to allow for heterogeneity. Section 5.2 evaluates the relationship between the model's optimal tariffs and applied tariffs in the data. Section 6 examines the robustness of our results including Section 6.3, which introduces endogenous lobbying to the model and tests its predictions empirically. Section 7 concludes.

2 Estimation

The estimator developed here is tasked with identifying pairwise trade elasticities for thousands of goods traded by hundreds of countries. This amounts to estimating millions of elasticities without a single reliable instrument. Our predecessors are Feenstra (1994) and Broda, Limão and Weinstein (2008), which rely on time series variation in prices and market shares of imported varieties of goods to identify trade elasticities. Given their focus is solely on import data from various countries, ensuring identification requires the assumption that the import demand and export supply elasticities are identical across all imported varieties of a good. The estimator developed here will also leverage time series variation in prices and quantities, but will demonstrate that the Feenstra (1994) estimator can no longer identify import demand and export supply with heterogeneity. We show how to overcome these issues by combining time series variation from multiple markets for the same traded good.

Soderbery (2015) argues that homogeneous import demand elasticities are supported by trade data, but imposing a common export supply elasticity is not. This is intuitive to us as the import demand elasticity generated from trade flow data, which records country level quantities and average prices, is plausibly characterized by constant elasticity substitution patterns across these country level aggregates. Conversely export supply elasticities characterize many tradeoffs within the production and trade of the exported variety that result in significant heterogeneity across countries.[8]

After writing down a parsimonious model of trade with exporter heterogeneity, we highlight the identification issues introduced by allowing for heterogeneous elasticities. We then show how to achieve identification by exploiting the structural differences between import and export markets for varieties of traded goods.[9] Here we argue that the time series variation in market shares *across* export destinations from a given origin differ from the variation in shares *within* an import market. We show that since these data series are generated from the same underlying supply process, their statistical differences can be used to identify unique pairwise export supply elasticities.

2.1 A Quantitative Model of International Trade

We start by specifying a quantitative model of trade that incorporates key assumptions from new trade theory. The model is flexible enough to accommodate structural estimation, yet parsimonious enough to apply to a a wide range of applications. In general, we are modeling a world with many importers and exporters trading a host of goods and varieties. Denote goods imported by any country I as $g \in G^I$ and varieties of these goods by v. In the following empirics, we define varieties of imported goods utilizing the Armington (1969) assumption. Explicitly, goods will be defined by their HS4 product category, and varieties of these goods consumed by a given importer will be determined by the origin of the exporter.

[8] This is not to say that the implications of heterogeneous import demand elasticities are not of potential importance. However, constant elasticity of substitution (CES) preferences still dominate the international trade literature. We thus opt to focus on extending our quantitative model of trade and developing an estimator that accounts for heterogenous export supply elasticities while maintaining the homogeneous CES import demand elasticity. Notably, the estimation methodology developed here could be applied to a setting with heterogeneous import demand elasticities as well. The costs associated with doing so are discussed in Section **3**.

[9] While we will utilize trade data reported by the exporter, it is not mandatory. Further discussion follows in the estimation section. Briefly, one can estimate the model as long as the import and export markets are clearly delineated in the data. This can be done by solely looking at trade flows reported by importers as long as the data record every country importing the good worldwide. This adjustment yields quantitatively and qualitatively similar results, and is valuable if we were concerned that measurement error in export data is systematically correlated with price and quantity variances. We take strides to address measurement error in the following to alleviate these concerns.

A representative consumer in each country maximizes her utility by choosing imports and domestic consumption. Following the standard in the literature, consumers aggregate over the composite domestic (D) and imported (X) goods. The subutility derived from the composite imported good will be given by a CES aggregation across imported varieties with a good-importer specific elasticity of substitution given by σ_g^I, where I denotes the importing country. Imports of a particular variety (v) of good (g) by country I are denoted by x_{gv}^I. Import demand is also augmented by a variety specific taste parameter b_{gv}^I. To focus our analysis, we will assume that consumers in I purchase a numeraire, c_0^I, and aggregate their consumption through Cobb-Douglas.[10] Under these assumptions, we write the utility obtained by a consumer in any importing country as,

$$U^I = c_0^I + \xi_X^I \sum_{g \in G^I} \phi_g^I log \left(\left(\sum_v (b_{gv}^I)^{\frac{1}{\sigma_g^I}} \, (x_{gv}^I)^{\frac{\sigma_g^I - 1}{\sigma_g^I}} \right)^{\frac{\sigma_g^I}{\sigma_g^I - 1}} \right) + \xi_D^I log(D^I). \tag{1}$$

The importer consumes fixed shares ξ_D^I and ξ_X^I of domestic and imported goods, respectively. Additionally, the imported composite is formed by consumption of fixed shares of each imported good given by Cobb-Douglas parameters ϕ_g^I. The separability of utility allows us to focus on prices and consumption of imported goods in the estimation.[11] This specification also implies that trade policy affects goods independently, which later will allow us to evaluate the efficacy of tariffs through their impact on consumption losses and terms of trade gains good by good.

Consumers maximize (1) subject to their budget constraint, which yields demand (x_{gv}^I)

[10]The numeraire abstracts away from labor market effects in order to focus on trade flows and their elasticities. Our preferences also rule out income effects in the model. Both assumptions prevail in the literature (c.f, Broda, Limão and Weinstein (2008)), but neither are necessary for estimation. The structural assumption facilitating estimation is the CES form of the imported variety nest.

[11]Notably, this assumption allows us to avoid explicitly specifying the form of the composite domestic good. Given the poor data on production and consumption of domestic goods for most (if not all) countries, it is impossible to respectably estimate supply and demand elasticities to construct the domestic composite (see Ardelean and Lugovskyy (2010) and Blonigen and Soderbery (2010) for a more thorough discussion).

for any variety (v) of an imported good (g) as a function of its price (p^I_{gv}),

$$x^I_{gv} = \xi^I_X \phi^I_g b^I_{gv} (p^I_{gv})^{-\sigma^I_g} (\mathcal{P}^I_g)^{\sigma^I_g - 1}, \tag{2}$$

where $\mathcal{P}^I_g = \left(\sum_v b^I_{gv} (p^I_{gv})^{1-\sigma^I_g} \right)^{\frac{1}{1-\sigma^I_g}}$ is the standard CES price index. All prices thus far are delivered prices in the importing country.

Given the structure of demand, we now need to specify exporter supply. We want export supply to be tractable enough to estimate, yet general and flexible enough to apply to many studies. To do so, we assume that exporter supply curves are upward sloping of the form,[12]

$$p^I_{gv} = exp(\eta^I_{gv})(x^I_{gv})^{\omega^I_{gv}}. \tag{3}$$

Exporters thus have unique supply curves for their variety both within and across countries. The destination-variety-specific inverse export supply elasticity is ω^I_{gv}. We also allow for unobservable variety specific supply shocks η^I_{gv} to facilitate estimation.

3 Empirical Strategy

Understanding the intuition of the estimator requires an explicit characterization of how our trade data are generated given the model. Supply and demand shocks fluctuate supply and demand curves. The well known issue with supply and demand estimation is that our market data only record equilibrium outcomes of prices and quantities, which translates into endogeneity from potential simultaneity in supply and demand. Since constructing feasible

[12] An upward sloping constant elasticity export supply curve of this nature was pioneered by Feenstra (1994), and has become standard with Broda and Weinstein (2006) and Broda, Limão and Weinstein (2008) for structurally estimating import demand and export supply elasticities. Additionally, recent deviations from Feenstra (1994) by Feenstra and Weinstein (2016) and Hottman et al. (2014) model a tighter link between exporter cost functions and export supply, but effectively assume export supply is isoelastic and upward sloping. Feenstra (2009) also provides a basis for this generic form of export supply curves. He shows that the equilibrium in Melitz (2003) follows a constant elasticity of transformation that to some extent parallels with an upward sloping constant elasticity export supply curve at the country level. Here we are following this literature regarding the shape of export supply, but are additionally allowing the export supply elasticity to be heterogeneous across varieties.

instruments to address this endogeneity is impossible given scope of the data (i.e., millions of elasticities would require millions of feasible instruments), we will utilize heteroskedasticity in supply and demand shocks to estimate the model. As with all of these so called heteroskedasticity supply and demand estimators, we also require that demand (taste) and supply (productivity) shocks be independent from one another. Shocks combine with equilibrium conditions to form the observed data.

Leamer (1981) demonstrates that we can use the variation in observed price and quantity outcomes to bound the parameters that generate our observed equilibria. Feenstra (1994) argues that if multiple varieties exported to the same destination have identical elasticity parameters, we can structurally estimate the model's parameters using Leamer (1981)'s insights. Here we are unwilling to assume that varieties from different origin countries are exported with identical supply elasticities. Consequently, looking within a single market (e.g., imports) no longer identifies either the demand or supply elasticity. By defining the export market and combining it with the import market, we will show how to achieve identification with heterogeneity. Specifically, our estimator leverages heteroskedastic differences in prices and quantities *across* versus *within* markets to produce consistent estimates of heterogeneous elasticities.

The following shows how to consistently estimate heterogeneous export supply and import demand elasticities for every importer-exporter-good triplet in the data. To do so, the method structurally estimates the preceding supply and demand model using only publicly available trade data for identification. We show explicitly how to utilize price and quantity variation across multiple markets to overcome endogeneity of supply and demand and achieve identification under heterogeneity. Finally, we discuss the assumptions governing shocks to supply and demand required by the estimator to yield consistent elasticity estimates along with potential threats to identification in the data.

3.1 Supply and Demand

Specifying a tractable empirical technique will depend on available data. Trade flows of goods between all countries are drawn from Comtrade and span 1991-2007. For consistency with previous studies we aggregate these data to the HS4 level.[13] The data are distributed in two parts. The first part consists of the values and quantities of goods exported by an origin to a destination as reported by the importer. The second part consists of the values and quantities of trade of the same good as reported by the exporter. We take advantage of both surveys in order to identify the elasticities of interest.[14] In the following, denote variables as reported by the importer with I, and those reported by the exporter with V.

The direction of trade will be important in what follows. Let $I \leftarrow V$ denote imports by I from V, and $V \rightarrow I$ are exports by V to I. To be clear, $I \leftarrow V$ and $V \rightarrow I$ are the same trade flow of the product. To remind the reader, gv signifies a unique importer-exporter pair trading the good (i.e., a variety). We will also rely on time-series variation for estimation, thus we denote a given year in the data by t.

Identification will exploit time series variation and statistical differences between import and export markets. To begin, take the perspective of the importer. The importer faces the delivered price $p_{gv}^{I \leftarrow V}$ for a given variety. In the data, prices are unit values and quantities are generally given in kilograms. The estimator will address measurement error in unit values through optimal weighting. Additionally, as in Feenstra (1994), we follow Kemp (1962) and convert the data into market shares in order to alleviate measurement error in quantities. Call the market share of a variety *within* a destination in period t, $s_{gvt}^{I \leftarrow V}$. From the quantitative model in Section **2.1**, we derive the exporter's market share in the importing country as,

$$s_{gvt}^{I \leftarrow V} \equiv \frac{p_{gvt}^{I \leftarrow V} x_{gvt}^{I \leftarrow V}}{\sum_v p_{gvt}^{I \leftarrow V} x_{gvt}^{I \leftarrow V}} = \left(\frac{p_{gvt}^{I \leftarrow V}}{\mathcal{P}_{gt}^{I}} \right)^{\sigma_g^I - 1} b_{gvt}^{I}. \tag{4}$$

Begin by first-differencing to remove any time invariant importer specific effects.[15] Then to absorb good-by-time specific effects, select a reference variety k and difference. This yields

[13] *ComTrade* data are generally available down to the more disaggregate HS6 product level. We have estimated, and make available estimates at the HS6 level. The themes of the paper are unaffected by the level of aggregation. Therefore, we opt to present the HS4 estimates as they are directly comparable to important results in the literature (i.e., Broda, Limão and Weinstein (2008)).

[14] While this paper utilizes trade data reported by the exporter, it is not mandatory. The details of this are further discussed in Section **3.2**. Ultimately, ignoring the exporter reported part of Comtrade data yields quantitatively and qualitatively similar results.

[15] Appendix A details precisely how the following equations are constructed, and how error terms are defined structurally.

market shares in logs,

$$\Delta^k log(s^{I \leftarrow V}_{gvt}) = -(\sigma^I_g - 1)\Delta^k log(p^{I \leftarrow V}_{gvt}) + \epsilon^I_{gvt}, \tag{5}$$

where Δ denotes the first difference and superscript k denotes differencing by reference country k.[16] ϵ^I_{gvt} are first and reference differenced unobservable variety specific taste shocks. Equation (5) is the demand curve of the importing country for the exported variety v.

Estimating the system also requires a supply curve for the variety delivered to I. Taking the same approach as above, we can write export supply in logs. After first- and reference-differencing we are left with,

$$\Delta^k log(s^{I \leftarrow V}_{gvt}) = \frac{\omega^I_{gv}+1}{\omega^I_{gv}} \Delta log(p^{I \leftarrow V}_{gvt}) - \frac{\omega^I_{gk}+1}{\omega^I_{gk}} \Delta log(p^{I \leftarrow K}_{gkt}) + \rho^I_{gvt}, \tag{6}$$

where ρ^I_{gv} are the unobserved differenced supply shocks. Notice that the export supply curve from any country is determined by the exporter's supply elasticity (ω^I_{gv}) relative to its competitor's supply elasticity (ω^I_{gk}). Consequently, applying Feenstra (1994) to the system cannot identify our trade elasticities with heterogeneity.[17]

Additional variation will be required to achieve identification. This variation can be found by taking the exporter's perspective. An exporter faces the same demand and supply elasticities in country I as specified above. However, the decisions made by an exporter V regarding goods shipped *across* destinations are substantively different than the outcomes *within* a destination. These differences are made apparent by calculating the share of total

[16] Δ^k thus denotes first- then referenced-differenced variables.

[17] In Appendix B we demonstrate the inability of Feenstra (1994) to identify our trade elasticities graphically. Fundamentally, Feenstra (1994)'s method of mapping data to hyperbolae and searching for the intersection of the hyperbolae no longer identifies elasticities with heterogeneity, as each hyperbolae is generated from a different export supply process. Explicitly, heteroskedasticity of supply and demand shocks within an importer alone are not sufficient to identify heterogenous elasticities.

export supply from country V represented by country I, which is

$$s_{gvt}^{V\to I} = \frac{p_{gvt}^{V\to I} x_{gvt}^{V\to I}}{\sum_I p_{gvt}^{V\to I} x_{gvt}^{V\to I}} = \frac{\left(p_{gvt}^{V\to I}\right)^{\frac{\omega_{gv}^I+1}{\omega_{gv}^I}} exp\left(\frac{-\eta_{gvt}^I}{\omega_{gv}^I}\right)}{\sum_I \left(p_{gvt}^{V\to I}\right)^{\frac{\omega_{gv}^I+1}{\omega_{gv}^I}} exp\left(\frac{-\eta_{gvt}^I}{\omega_{gv}^I}\right)}. \tag{7}$$

Again we want to eliminate time and country specific effects. To do so, take logs, first difference, then choose a reference *destination* (j) and difference. This yields,

$$\Delta^j log(p_{gvt}^{V\to I}) = \frac{\omega_{gv}^I}{\omega_{gv}^I+1} \Delta log(s_{gvt}^{V\to I}) - \frac{\omega_{gv}^J}{\omega_{gv}^J+1} \Delta log(s_{gvt}^{V\to J}) + \rho_{gvt}^V, \tag{8}$$

where ρ_{gvt}^V are the unobserved supply shocks. Equation (8) is the supply curve for the exported variety *across* destinations. The supply curve again depends upon the export supply elasticity in I relative to the reference. However, the reference country is now defined as the same variety shipped by an exporter to a different destination.

Next we define the demand curve across the exporter's destinations. In logs and first- and reference-differences, demand is given by,

$$\Delta^j log(s_{gvt}^{V\to I}) = (1 - \sigma_g^I) \Delta log(p_{gvt}^{V\to I}) - (1 - \sigma_g^J) \Delta log(p_{gvt}^{V\to J}) + \epsilon_{gvt}^V, \tag{9}$$

where ϵ_{gvt}^V are the relative taste parameters across destinations. Relative prices and shares are thus determined by differences in the elasticity of substitution and market composition of each of the exporter's destination markets.

Here it is worth spelling out the intuition of the estimator so that the following explicit formulation is clear. First we need to acknowledge the data generating process in our trade data. Supply and demand shocks fluctuate our four supply and demand curves. Shocks then combine with equilibrium conditions to form the observed data. Leamer (1981) demonstrates that we can use the variation in shocks to construct hyperbolae that bound the parameters underlying our observed equilibria.[18] Feenstra (1994) argues that multiple varieties following the same underlying elasticity parameters allows us to estimate supply and demand elasticities by minimizing the distance between hyperbolae. The preceding makes evident that supply and demand for a variety in a single (import or export) market depends on the differences between the heterogenous elasticities in that market. Consequently, minimizing the distance between the hyperbolae generated by multiple varieties within a market cannot identify elasticities with heterogeneity. The following formalizes how to combine price and quantity variation of a particular variety (i.e., hyperbolae) *across* multiple markets to identify our elasticities.

3.2 Identification and Estimation

Notice that while market outcomes for exporters and importers are related, they are not identical. Market share *within* a destination captured by a particular exporter (Equation (4)) depends on the composition of that particular market (e.g., other exporters to that market). Market share of a particular importer *across* an exporter's destinations (Equation (7)) depends on the composition of the set of destination markets (e.g., other importers of the exported variety). Differential relationships between the outcomes of an exporter within markets versus across markets will allow us to identify heterogeneous export supply elasticities by jointly estimating Equations (5), (6), (8) and (9). In Leamer (1981) terms, differences in the hyperbolae generated by looking at fluctuations in prices and shares across markets versus the hyperbolae generated by looking at fluctuations in prices and shares within markets will be utilized to achieve identification.[19]

First we need to motivate the realism of differences between export markets and import

[18] Leamer (1981) demonstrates hyperbolae from a time series of price and quantity data are defined as:

$$(\beta - \frac{cov(p,x)}{var(p)})(\Theta - \frac{cov(p,x)}{var(p)}) = \left(\frac{cov(p,x)^2}{var(x)var(p)} - 1\right)\left(\frac{var(x)}{var(p)}\right)$$

where Θ is the true supply elasticity and β is the true demand elasticity. For those unfamiliar with Leamer (1981) hyperbolae, Soderbery (2015) surveys the methodology using actual data to construct hyperbolae and estimate import demand and export supply elasticities using Feenstra (1994)'s method.

[19] In other words, we require that the export and import hyperbolae for any origin destination pair are not asymptotically identical.

markets in reality. In the raw data, variation in market shares realized across export destinations do in fact look sufficiently different from market shares captured within a destination. To provide a specific example, Canada exported about $\$34Bill$ of HS 8703 (automobiles) to the US in 2006. The share of the import market captured by Canada in the US was 27%. However, the share represented by the US for the Canadian export market was almost four times the size at 96%. Additionally, the raw correlation of these market shares over time from 1991-2007 was 0.52. An added source of variation in the data will come from the differences in reported shipped and delivered prices (unit values), which capture differences in prices received by exporters versus those faced by importers. The raw correlation between shipped and delivered prices for Canadian exports of autos to the US is 0.71.[20] Variation of this sort is exactly what is required by the estimator.[21] Simply, as long as the fluctuations in prices and shares over time in the two markets are *not identical* the identification strategy is sound.

We begin by assuming, as each of our predecessors have done, that supply and demand shocks to a variety are uncorrelated over time. Specifically, $E[\epsilon^I_{gvt}\rho^I_{gvt}] = 0$ and $E[\epsilon^V_{gvt}\rho^V_{gvt}] = 0$.[22] We can then multiply the residuals from the supply and demand equations for the

[20]For the full sample of auto imports and exports from 1991-2007, the average correlation over time within and importer exporter relationship between shipped and delivered prices is 0.51 and between import and export market shares is 0.67.

[21]Theoretically, it is beneficial to exploit differences between shipped and delivered prices to further ensure hyperbolae are not asymptotically identical. We will thus opt to utilize both importer and exporter reported trade values in Comtrade. Feenstra and Romalis (2014) also rely on both sections of Comtrade, which provides some measure of support. However, it is worth acknowledging the critiques levied by Hummels and Lugovskyy (2006) regarding the accuracy of the exporter reported data in particular. We do address the potential introduction of measurement error following Broda and Weinstein (2006). Specifically, we follow their intuitive weighting and the inclusion of a weighted constant term. As long as what remains after our control for measurement error is not correlated with price and quantity variances and covariances our strategy is sound. Finally, if we were still concerned about the accuracy of exporter reported data, it is reassuring that the estimator presented here does not require both importer and exporter reported data. One could easily calculate the import and export shares needed for estimation using only importer reported data as long as the researcher constructs the variables and estimator using the totality of world trade. The fundamental goal is defining multiple markets with price and market share variation that is sufficiently different but the underlying elasticities are the same. We expect the differences in import and export shares constructed using only import data would provide enough variation to generate unique hyperbolae even without exploiting the differences between shipped and delivered prices.

[22]Notably, it need not be the case that $E[\epsilon^I_{gvt}\epsilon^V_{gvt}] = 0$ and $E[\rho^I_{gvt}\rho^V_{gvt}] = 0$, which is violated by the construction of the model. Intuitively, the estimator does not put any restrictions on the correlation of demand shocks or supply shocks within and across countries. For example, a global crisis decreasing demand for all imported varieties or a technological breakthrough increasing supply for all exported varieties does

importer and exporter markets to generate consistent estimating equations. For the import market we multiply the residuals from (5) and (6) to get,

$$
\begin{aligned}
\Delta^k log(p^{I\leftarrow V}_{gvt})^2 =& \tfrac{\omega^I_{gv}}{(1+\omega^I_{gv})(\sigma^I_g-1)}\Delta^k log(s^{I\leftarrow V}_{gvt})^2 + \tfrac{\omega^I_{gv}}{1+\omega^I_{gv}}\Delta^k log(s^{I\leftarrow V}_{gvt})\Delta^k log(p^{I\leftarrow V}_{gvt}) \\
& - \tfrac{1}{\sigma^I_g-1}\Delta^k log(s^{I\leftarrow V}_{gvt})\Delta log(p^{I\leftarrow V}_{gvt}) + \tfrac{\omega^I_{gv}(1+\omega^I_{gk})}{\omega^I_{gk}(1+\omega^I_{gv})(\sigma^I_g-1)}\Delta^k log(s^{I\leftarrow V}_{gvt})\Delta log(p^{I\leftarrow K}_{gkt}) \\
& + \tfrac{\omega^I_{gv}-\omega^I_{gk}}{\omega^I_{gk}(1+\omega^I_{gv})}\Delta^k log(p^{I\leftarrow V}_{gvt})\Delta log(p^{I\leftarrow K}_{gkt}) + u^I_{gvt},
\end{aligned} \tag{10}
$$

where the error term $u^I_{gvt} = \frac{\omega^I_{gv}\rho^I_{gvt}\epsilon^I_{gvt}}{(1+\omega^I_{gv})(\sigma^I_g-1)}$ is zero in expectation.[23] To estimate the model we will build on the methodology proposed by Feenstra (1994).[24] Taking exporter by exporter averages over time transforms Equation (10) into a linear regression of price variances on share variances and price-share covariances (i.e., hyperbolae). However Equation (10) is unidentified, so that applying Feenstra (1994)'s weighted least squared to Equation (10) cannot consistently estimate our heterogeneous elasticities.

To overcome this identification problem, we produce a similar estimating equation for

not violate the model. It is worth noting that we make the intuitive assumption that supply shocks hitting a particular exporter of a particular good are allowed to be destination specific, but in expectation the difference between these export supply shocks is zero (i.e., $E[\rho^V_{gvt}] = 0$). These potential threats to the estimator are discussed further at the end of this Section.

[23]Note that Equation (10) is identical to Feenstra (1994) if export supply elasticities are homogeneous (i.e. $\omega^I_{gv} = \omega^I_g \ \forall\ v$). It is tempting to argue that we could more simply identify Equation (10) with heterogeneous elasticities by iterating Feenstra (1994) on subsamples of data. However, this type of ad hoc procedure is not identified. The thought bears a resemblance to the critique levied by Frisch (1933) agains Leontief (1929) which attempted to solve the consistency problem when estimating supply and demand elasticities by splitting samples to create intersections of hyperbolae. While Soderbery (2015) experiments with Feenstra (1994) on subsamples of data, the exercise is purely illustrative and, without well defined instruments, only provides suggestive evidence of exporter heterogeneity. The following will show how to appropriately overcome the identification problem and consistently estimate heterogeneous elasticities without relying on instrumental variables.

[24]Feenstra (1994) demonstrates that applying WLS on country averages (or equivalently 2SLS with country indicators as instruments) to Equation (10) yields consistent estimates of the supply and demand elasticities when both are homogeneous.

the export market. Multiplying our error terms from (8) and (9) together yields,

$$\begin{aligned}
\Delta^j log(p_{gvt}^{V\to I})^2 =& \tfrac{\omega_{gv}^I}{(1+\omega_{gv}^I)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to I})^2 + \tfrac{\omega_{gv}^I(\sigma_g^I-2)-1}{(1+\omega_{gv}^I)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to I})\Delta log(p_{gvt}^{V\to I}) \\
&+ \tfrac{\omega_{gv}^J}{(1+\omega_{gv}^J)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to J})^2 + \tfrac{1-\omega_{gv}^J(\sigma_g^I-2)}{(1+\omega_{gv}^J)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to J})\Delta log(p_{gvt}^{V\to I}) \\
&+ \tfrac{1-\omega_{gv}^J(\sigma_g^J-2)}{(1+\omega_{gv}^J)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to J})\Delta log(p_{gvt}^{V\to J}) + \tfrac{\omega_{gv}^I(\sigma_g^J-2)-1}{(1+\omega_{gv}^I)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to I})\Delta log(p_{gvt}^{V\to J}) \\
&- \tfrac{\omega_{gv}^J(1+\omega_{gv}^I)+\omega_{gv}^I(1+\omega_{gv}^J)}{(1+\omega_{gv}^I)(1+\omega_{gv}^J)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to I})\Delta log(s_{gvt}^{V\to J}) + \tfrac{\sigma_g^I-\sigma_g^J}{\sigma_g^I-1}\Delta log(p_{gvt}^{V\to J})^2 \\
&+ \tfrac{\sigma_g^J-\sigma_g^I}{\sigma_g^I-1}\Delta log(p_{gvt}^{V\to J})\Delta log(p_{gvt}^{V\to I}) + u_{gvt}^V, \qquad (11)
\end{aligned}$$

where the error term $u_{gvt}^V = \frac{\rho_{gvt}^V \epsilon_{gvt}^V}{\sigma_g^I-1}$ is zero in expectation. Combining Equations (10) and (11) provides us the necessary variation to identify all heterogeneous elasticities. To estimate the full model, we apply Feenstra (1994)'s methodology to convert both equations to regression of price variances on share and price variances and covariances (roughly, we map Leamer (1981) hyperbolae into data). Our estimation then chooses the elasticities which jointly minimize the distance between Leamer (1981) hyperbolae across the import and export markets.

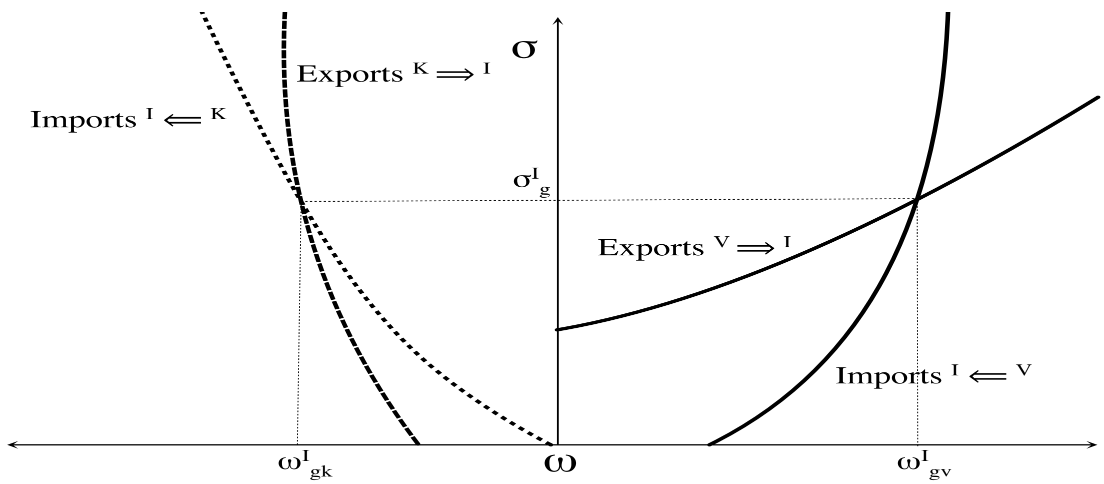
We apply the estimator looking within an importer-good pair across exported varieties over time. Multiple exporters jointly identify the import demand elasticity. Combining variation from import and export flows then pins down the pairwise export supply elasticities. In practice, we simultaneously estimate Equations (10) and (11) with a nonlinear seemingly unrelated-regression constrained to the feasible region where $\sigma > 1$ and $\omega > 0$.[25] Estimates of the elasticities are consistent provided the import and export hyperbolae for each importer-

[25] One concern with existing trade data is measurement error in prices (unit values) and quantities (product weight). As mentioned above, the use of market shares alleviates much of our concern regarding the measurement of quantities. Using unit values in place of transaction prices necessitates a weighting scheme. Given the use of both import and export data and the context of the problem, we adopt the weights proposed by Broda and Weinstein (2006) and include an importer-exporter specific constant. Specifically, the data are weighted by $T_{gv}^{3/2}\left({}^1/_{x_{gvt}} + {}^1/_{x_{gvt-1}}\right)^{-1/2}$, as we expect greater accuracy in the recorded data between large ($\uparrow x_{gvt}$) and persistent ($\uparrow T_{gv}$) trading partners. Broda and Weinstein (2006) demonstrate that these weights accompanied by a constant in estimation correct for random measurement error in prices along with measurement error that may be decreasing in the amount of total trade. Additionally, this weighting scheme matches our intuition derived from hyperbolae – we will give more weight to hyperbolae generated by large trading partners in the estimation. Soderbery (2015) discusses the appropriate weighting of hyperbolae in great detail. In the case of Feenstra (1994) LIML is the superior scheme. Here the problem is exponentially more computationally intensive and not amenable to LIML, thus we opt for the intuitive weighting scheme.

exporter-product triplet are not asymptotically proportional.[26]

Figure 1 presents the intuition of the estimator graphically. Consider three countries denoted I, K and V trading good g. Country I imports varieties of g from V and K. We can then map prices and quantities following Equation (10) into hyperbolae (Imports $I \Longleftarrow V$ and Imports $I \Longleftarrow K$). Figure 1 assumes we know for certain the import demand σ_k^I and export supply elasticities ω_{gk}^I and ω_{gv}^I in the market. Looking solely at the import hyperbolae, notice we cannot identify the three elasticities with only the two import hyperbolae. Our identification strategy is to provide additional information (i.e., hyperbolae) from the export market. Realizing exporters V and K export to (many) other markets allows us to map Equation (11) into the hyperbolae Exports $V \Longrightarrow I$ and Exports $K \Longrightarrow I$.

Figure 1: Combining Importer and Exporter Hyperbolae



By combining importer and exporter hyperbolae, Figure 1 displays our identification

[26]Mathematically, this amounts to

$$\frac{\sigma^2_{\epsilon^I_{gjt}} + \sigma^2_{\epsilon^I_{gkt}}}{\sigma^2_{\epsilon^K_{gjt}} + \sigma^2_{\epsilon^J_{gkt}}} \neq \frac{\sigma^2_{\rho^I_{gjt}} + \sigma^2_{\rho^I_{gkt}}}{\sigma^2_{\rho^K_{gjt}} + \sigma^2_{\rho^J_{gkt}}}$$

for every variety $j \neq k$, where σ^2 is the variance of the subscripted shock process (e.g., $\sigma^2_{\epsilon^I_{gjt}}$ is the variance of ϵ^I_{gjt}, which are the demand shocks in country I for exports originating from country J). Intuitively, the above condition describes how shocks within a market must differ from shocks across markets to ensure that importer and exporter hyperbolae are not asymptotically proportional.

strategy.[27] Notice that the intersections of the importer and exporter hyperbolae in the import and export markets for multiple varieties can be combined to identify heterogeneous export supply elasticities. Notice that the intersections of the hyperbolae in the two markets jointly pin down the import demand elasticity since all exporters to I face the same value. With the demand elasticity in hand, our estimator can then simultaneously identify the heterogeneous export supply elasticities by combining hyperbolae from the import and export markets.[28]

Figure 1 presents the ideal situation where all of the hyperbolae cross and line up directly at the import demand elasticity. The reality of the data is that this clean result will be rare – hyperbolae in general may cross multiple times at different values in the feasible region or not cross at all. This necessitates our estimation strategy where we jointly estimate the demand elasticity and use it to identify the heterogeneous export supply elasticities.

Our estimation strategy for import demand and export supply elasticities fits with a small but growing set of structural estimators in trade. Feenstra and Weinstein (2016) propose a structural estimator based on translog preferences to estimate exporter markups. Feenstra and Romalis (2014) estimate an importer specific quality distribution parameter. Notably, their estimators are not tasked with uncovering pairwise heterogeneity between importers and specific exporters, but rather potential distributional differences across exported varieties to the US. Using a similar methodology, Hottman, Redding and Weinstein (2014) leverage detailed scanner data in the US to uncover quality, costs and markups across goods sold by particular US retailers. In comparison, we analyze the heterogeneous relationships both within and across all traded goods and countries.

A valuable difference between our estimator and the literature are the data required for estimation. Our technique needs only readily available data on trade flows to be implemented. Feenstra and Weinstein (2016) requires measures of product specific Herfindahl

[27] Appendix B provides more detail on the construction of importer and exporter hyperbolae along with the identification issues introduced by heterogeneity.

[28] Theoretically, one could use the intuition of Figure 1 to estimate a model with both heterogeneous import demand and export supply elasticities. However, given the results of Soderbery (2015), the prevalence of CES demand in international trade, and the tax this would place on the data, we focus on extending the estimator to heterogeneity in export supply elasticities.

indexes that were specially constructed in the US for their study, and do not exist for most (if not all) other countries. Feenstra and Romalis (2014) relies on highly detailed trade cost and wage data across countries that are not readily available. Hottman, Redding and Weinstein (2014) utilize proprietary scanner data as they require granular transaction level data, which presents significant hurdles to extend their estimator beyond the US or even across the full set of products imported by the US.

Before presenting the estimates, it is worthwhile to discuss some potential correlation patterns across countries that will and will not call the estimator into question. The stalwart assumption that we (and the preceding literature) require is that supply and demand shocks from both the importer and exporter perspective are uncorrelated (i.e., $E[\epsilon^I_{gvt}\rho^I_{gvt}] = 0$ and $E[\epsilon^V_{gvt}\rho^V_{gvt}] = 0$). This assumption cannot be relaxed. While this assumption is a mainstay in the literature (i.e., Feenstra (1994) and extensions), it notably rules out models of endogenous quality choice where there is a mechanical correlation between importers' tastes and exporters' supply shocks.

However, this assumption does not rule out a host of other potential patterns in the data. Suppose for instance that Japan's productivity increases over time such that its supply curves to all destinations shift out systematically. This would imply that $E[\rho^V_{gvt}\rho^I_{gvt}] > 0$ for the Japanese variety. As long as importers' taste for the Japanese variety is not increasing or decreasing *due to* the persistent supply shock, our estimator is consistent. Alternatively, suppose all importers' taste for say Germany's variety increase. This would imply that $E[\epsilon^V_{gvt}\epsilon^I_{gvt}] > 0$ for German exports. Again, as long as German supply shocks are not increasing or decreasing due to this persistent demand shock our estimator is consistent.

One may argue that a persistent supply shock to a large country, such as Japan, will have feedback into importers' price indexes and total expenditures for a good (in fact, we will make this argument later when we analyze market power and optimal tariffs). This argument poses no threat to the estimating equation from the importer perspective, as the $E[\epsilon^I_{gvt}\rho^I_{gvt}]$ depends only on importer taste and exporter supply shocks, which we assume are fundamentally uncorrelated. However, from the exporter's perspective, ϵ^V_{gvt} does contain importer price indexes. We argue that even with large countries potentially impacting price indexes through their export supply shocks, $E[\epsilon^V_{gvt}\rho^V_{gvt}]$ still equals zero. This argument is based on observing that since ρ^V_{gvt} is structurally the reference difference of first-differenced export supply shocks for the same exporter, it is zero in expectation over time. If we were unwilling to assume $E[\rho^V_{gvt}] = 0$, the structure of the model, data, and estimator do allow the practitioner to decompose ϵ^V_{gvt} by including relative price indexes in the joint estimation rather than the error term. While this is a viable alternative, we are confident that the intuition of $E[\rho^V_{gvt}] = 0$, combined with our strategy to correct for measurement error (see Footnote 18 above), appropriately addresses these concerns.[29]

Fundamentally, our estimator relies on heteroskedasticity in supply and demand shocks. In Feenstra (1994), heteroskedasticity in shocks across exporters of a particular good are the key. He showed how this variation combined with homogeneous elasticities led to identification. Our estimator leverages this same variation in the data, but also requires heteroskedasticity in shocks across importers of the exported good. This additional source of variation, which we have highlighted is prevalent in the data, is how we achieve identification of the heterogenous elasticities. The following presents our estimates, and provides some tests of their reasonableness given our intuition.

4 Elasticity Estimates

The only data required for estimation are trade flows associated with country pairs across goods – here we rely on Comtrade data from 1991-2007, which are readily available. The data contain 1243 goods at the HS4 level and 192 importing and exporting countries.

Not all countries trade all goods with one another, but we are still tasked with estimating approximately 3 million export supply elasticities (the number of importer-exporter-goods in the data) and 200,000 (the number of importer-goods in the data) import demand elas-

[29] Additionally, we have estimated the alternative strategy discussed here by controlling for Sato-Vartia price indexes and expenditure in the estimation rather than the error term. For the products we have estimated, this alternative yields almost identical results. The within importer correlation of the export supply elasticities is 0.91 on average, and the median percentage difference is 0.000002% with an interquartile range of -0.00003% and 0.04%. The import demand elasticities are even closer to one another with 90% if the estimates lying between -0.07% and 0.02% within one another. These results are highly supportive of our assumptions and preferred methodology, since including the price index as a control has little to no effect on the estimates.

ticities. Simply, this is computationally infeasible.[30] To reduce the parameter space, assume small countries in the same region have identical supply technologies. This is a restrictive assumption for these countries. However, it is necessary for computational tractability, and still considerably more disaggregate than any preceding study. Table 1 lists the regions designated along with their total imports and exports.[31]

Table 1: Regions and Trade

Country			GDP ($Billion)		Total Trade ($Billion)	
Name	Code	Count	Average	Total	Imports	Exports
Australia	AUS	1	768.18	768.18	189.03	126.30
Brazil	BRA	1	1067.96	1067.96	154.55	153.13
Canada	CAN	1	1251.46	1251.46	527.79	467.53
China & Hong Kong	CHN	2	1574.23	2872.15	1791.36	2814.51
Germany	DEU	1	2906.68	2906.68	1473.64	2120.57
France	FRA	1	2230.72	2230.72	908.88	834.60
Great Britain	GBR	1	2345.02	2345.02	855.11	656.88
India	IND	1	906.27	906.27	238.88	195.04
Italy	ITA	1	1844.75	1844.75	713.24	818.41
Japan	JPN	1	4340.13	4340.13	789.13	1296.27
Mexico	MEX	1	839.18	839.18	442.62	322.61
Russia	RUS	1	986.94	986.94	265.06	259.23
United States	USA	1	13201.82	13201.82	2729.85	1775.20
Region						
African	AFR	43	83.39	941.65	304.65	281.94
Asian	ASA	38	248.54	2994.04	2179.07	2082.72
Caribbean	CAR	16	17.68	64.67	34.40	22.62
Northern/Western Europe	NWU	18	328.79	3278.56	2375.50	2354.46
Oceania	OCE	11	90.15	113.45	42.03	20.10
South American	SAM	20	98.64	962.40	310.57	275.90
Southern/Eastern Europe	SEU	22	292.89	2716.01	1591.13	1038.48

Notes: GDP is total gross domestic products reported by *CEPII* in US dollars for 2006. Imports and exports are in US dollars from ComTrade in 2006.

[30]There are 3 million importer-exporter-product triplets in the data, which implies 3 million export supply elasticities to be estimated. The following thus makes some assumptions to reduce the parameter space. After these assumptions, we still estimate over 1.2 million export supply and 125,000 import demand elasticities. The estimation routine requires two full weeks to complete running concurrently on three computers with 4 processors using StataMP.

[31]We have tried to follow the United Nations Statistical Division's definitions of country regions, which can be found here `https://unstats.un.org/unsd/methods/m49/m49regin.htm`. The full listing of countries and their assigned regions is given by Appendix Table A2.

Applying the estimator requires imports from at least two countries that both export to at least one other destination for a minimum of three periods. These are relatively weak requirements conceptually, but in practice the intersection of trade data and the estimator meeting its minimum requirements reduces the sample of trade flows from around 1.25 millions observations per year to 0.8 million. Reassuringly, the remaining data account for 94% of all trade by value globally.[32]

Table 2: Summary Statistics: Elasticities and Country Size

		σ_g^I			ω_{gv}^I		
Importer	Obs	Mean	Median	MAD†	Mean	Median	MAD†
Australia	17923	3.727	2.997	0.474	38.56	0.798	0.549
Brazil	15664	3.372	2.847	0.492	31.42	0.734	0.562
Canada	17896	3.702	3.051	0.621	52.07	1.158	0.734
China & Hong Kong	39393	3.395	2.897	0.554	189.74	1.270	0.770
Germany	35880	3.608	3.029	0.505	101.31	1.206	0.572
France	30124	3.351	2.972	0.411	40.26	0.828	0.468
Great Britain	31064	3.333	2.977	0.363	18.56	0.853	0.453
India	16496	3.832	2.996	0.529	54.01	0.752	0.552
Italy	30608	3.439	3.012	0.478	43.26	0.798	0.451
Japan	21574	3.640	2.985	0.543	123.13	1.214	0.758
Mexico	15715	3.625	2.925	0.526	29.63	0.890	0.697
Russia	20310	3.621	3.007	0.563	204.18	0.773	0.524
United States	34443	3.937	2.940	0.383	39.17	1.203	0.541
African	116143	3.921	2.656	0.393	131.02	0.581	0.555
Asian	261285	3.282	2.827	0.494	69.40	0.502	0.449
Caribbean	18925	3.537	2.852	0.503	38.09	0.669	0.605
Northern/Western Europe	216373	3.127	2.843	0.446	83.64	0.648	0.445
Oceania	16915	3.829	2.991	0.642	59.88	0.732	0.638
South American	104882	3.425	2.882	0.425	30.04	0.588	0.421
Southern/Eastern Europe	214013	3.251	2.857	0.457	24.61	0.665	0.439
World	1275626	3.405	2.878	0.465	68.55	0.690	0.493

Notes: For exposition and comparability to previous studies, σ_g^I is truncated at 131.05, and the top and bottom 0.5% of ω_{gv}^I are dropped. † MAD stands for the median absolute deviation.

Table 2 summarizes our estimates across importers. The median absolute deviation (MAD) indicates that around 75% of our export supply elasticities lie between 0.197 and

[32]Section **5.2.1** is devoted to comparing my estimates to those of Broda, Limão and Weinstein (2008), but it is worth noting that their analysis covers data with 250,000 observations over 15 importers that only accounts for 8% of trade.

1.183 with a long right tail.[33] Our demand elasticities have a similar long right tail and an interquartile range of 2.41–3.34, which is very much in line with the literature.[34]

Additionally, our estimated elasticities vary considerably across goods and importers and even within goods across exported varieties. To be specific, variation in our estimated inverse export supply elasticities explained by importer-product fixed effects is only 72%. Remaining variation in the estimates comes from heterogeneity across exported varieties within an imported good. Much of the variation in our estimates is thus a result of exporter heterogeneity. Notably, variation in homogeneous export supply elasticity estimates, such as those estimated by Broda and Weinstein (2006) and Broda, Limão and Weinstein (2008), is fully explained by importer-product fixed effects.

A useful interpretation of the inverse export supply elasticity ω^I_{gv} is as a measure of importer market power. Since ω^I_{gv} governs the degree of passthrough of a shock (e.g., tariffs) to delivered prices, large ω^I_{gv} corresponds with a high degree of importer market power as more inelastically exported varieties only weakly pass through shock-induced price changes. Our estimates suggest countries with the highest GDPs tend to have the most market power, as their imports have the largest median inverse supply elasticities. Of these countries, Japan (JPN), China (CHN), Germany (DEU) and the US (USA) seem to have the highest degree of market power on their median import. As we may expect, regions with the least market power are the small Asian (ASA), South American (SAM) and African (AFR) countries. One surprising feature of the summary statistics is the relatively high median estimated market power for Oceanic (OCE) and Caribbean (CAR) countries.

We will explain these moments in the estimates by controlling for intuitive patterns of market power subsequently. Yet it is worth noting here that these patterns in the raw estimates are a direct consequence of compositional heterogeneity in the goods and partners

[33] Robust standard errors for each estimate is available upon request. For the sake of space, further discussion of standard errors is undertaken in Appendix C.

[34] While the mean and median of the import demand elasticities estimated here are lower than those in previous studies (c.f., Broda, Limão and Weinstein (2008)), they are very much in line with Soderbery (2015) who argues previous studies mask significant bias in the standard estimator and provides a correction. This paper is focused on the role of export supply elasticities. Yet, it is worth noting that there is a sense by which accounting for heterogeneity in export supply tames our estimates of import demand, as our estimates are not as volatile as previous studies and still follow intuitive patterns across products.

that comprise importers' trade. This heterogeneity is precisely the feature of the data the estimator is tasked with uncovering.

4.1 Product Differentiation and Market Power

Here we consider some tests in the spirit of Broda, Limão and Weinstein (2008) of our intuition regarding the relationships between importer-exporter and country-good characteristics that we expect to underlie market power. First, we explore the relationship between product differentiation and market power and the substitutability of goods. Second, we examine the role of shares of countries' trade in forming market power across goods. In the analysis we will highlight the role and importance of heterogeneous elasticities for our intuition.

Conceptually, we believe importers have more market power over imports of differentiated goods since the equilibrium price of a differentiated good may be more affected by a single importer. For instance, if US demand for German microscopes (HS 9011) falls and Germany decreases prices globally, there will be relatively weak substitution by other countries toward German microscopes due to the differentiated nature of this industry. Consequently, the equilibrium world price for German microscopes may fall substantially in response to the shock in the US market, which is our definition of importer market power. Conversely, we would expect strong substitution by other countries with price fluctuations if the good is more homogenous (e.g., steel sheet). Plainly, we expect differentiated goods to present with higher ω^I_{gv}. A more direct comparison can be made with the demand elasticity. We expect homogenous goods to be more substitutable, and thus have higher estimated import demand elasticities (σ^I_g).[35]

Table 3 explores whether product differentiation relates to our estimated elasticities through various reduced-form regressions of our inverse export supply and import demand

[35] Perpetuating the US-Germany example, we estimate a relatively large export supply elasticity (3.25) and small import demand elasticity (2.69) for US imports of German microscopes (HS 9011). Conversely, we estimate a relatively small export supply elasticity (0.09) and large import demand elasticity (4.51) for US imports of German steel sheet (HS 7208). These estimates thus support the intuition that the US has strong market power over imports of more differentiated products and more differentiated products tend to present lower demand elasticities.

elasticities on indicators of product differentiation.[36] Considering the long right tail of the distributions of our elasticity estimates, our regressions are run in logs. Regardless of specification, Table 3 demonstrates that importers have lower market power on average in markets for less differentiated goods. Column (1) estimates that the average differentiated good is supplied with an inverse export supply elasticity triple the size of the average homogenous good.

Table 3: Trade Elasticities and Product Differentiation

	$log(\omega^I_{gv})$			$log(\sigma^I_g)$	
	(1)	(2)	(3)	(4)	(5)
Reference Good	-1.816^{***}	-1.830^{***}	-0.665^{***}	0.027^{***}	0.027^{***}
	(0.012)	(0.011)	(0.061)	(0.001)	(0.001)
Homogeneous Good	-3.192^{***}	-3.260^{***}	-2.129^{***}	0.080^{***}	0.079^{***}
	(0.027)	(0.027)	(0.065)	(0.002)	(0.002)
Importer FEs	No	Yes	Yes	No	Yes
Importer × Non-Differentiated Good FEs	No	No	Yes	No	No
R^2	0.033	0.044	0.049	0.002	0.005
Obs.	1229710	1229710	1229710	1229710	1229710

Notes: Rauch (1999)'s conservative classification is used to indicate differentiated, reference priced, and homogeneous goods (the liberal classification yields identical results). Robust standard errors are in parentheses where, * p<0.10, ** p<0.05, *** p<0.01 indicate significance.

The heterogeneity in our estimates allows us to analyze whether certain countries have different degrees of market power across types of goods. We thus include various fixed effects to examine whether the relationship between product differentiation and trade elasticities varies across importers. Column (2) begins by adding importer fixed effects. Column (3) pushes the estimates further by exploring whether countries have differential market power across types of goods via importer fixed effects interacted with a product differentiation dummy. In all of these regressions countries have higher market power for differentiated goods on average. Columns (4)-(5) extend the exercise to the import demand elasticity estimates. We can see that our estimates of σ^I_g are highly correlated with product differentiation. As

[36] Product differentiation is defined according to Rauch (1999) who classifies products as either differentiated, reference priced or homogeneous.

we would expect, differentiated goods have the lowest elasticities of substitution, and in increasing order, reference and homogenous goods have higher elasticities.

Table 4: Rankings of Average Market Power

	Market Power Ranking		
Importer	All Goods	Differentiated Goods	Non-Differ Goods
Germany	1	2	2
China & Hong Kong	2	1	8
United States	3	3	5
Japan	4	4	4
Italy	5	8	7
Southern/Eastern Europe	6	5	17
Canada	7	7	10
France	8	10	6
Great Britain	9	9	9
Northern/Western Europe	10	6	18
Russia	11	11	14
South American	12	13	15
Australia	13	15	11
India	14	18	3
Oceania	15	17	13
Mexico	16	16	16
Asian	17	12	20
Brazil	18	19	12
African	19	14	19
Caribbean	20	20	1

Notes: Rankings are determined by sorting the fixed effects in Table 3. *All Goods* sorts the fixed effects from Column (2), while *Differentiated* and *Non-Differ* sort the fixed effects from Column (3).

The fixed effects in the preceding regression can be used to rank countries by their median market power across types of goods after controlling for product differentiation. Table 4 presents the estimated ordering of each region's market power by these fixed effects. We can see that Germany, the US and China have the highest degree of market power across all goods. Outside of the US, North American countries have noticeably low market power. This feature is likely due to the strong ties Canada and Mexico have with the US and an inability to exert market power on US exports.

For differentiated goods, market power rankings follow a similar ordering to that of all goods. One noticeable departure is market power in Asian (ASA) countries over differentiated goods. Overall, Asian countries rank seventeenth, but in terms of differentiated goods they have the twelfth highest degree of market power. This is quite intuitive as this region contains countries such as Taiwan and Korea which are significant importers of high-tech goods.

Additionally, we believe Asia's reliance on imported commodities leads to the lowest level of market power across non-differentiated goods. Exactly the opposite story is revealed for India. India has one of the lowest levels of market power for differentiated goods, but the third highest degree of market power for non-differentiated goods. India's imports of non-differentiated goods are predominantly supplied by regional trade partners, of which India is an important export destination. These regional trade linkages have been long associated with importer market power.[37] While these rankings support intuitive patterns of market power varying across types of goods and the composition of a country's imports, a more detailed analysis is warranted.

The preceding looks across products to make cross country comparisons. Table 5 now looks within products by including product fixed effects in order to compare our market power estimates across country-pair relationships. Column (1) begins with the assertion that country size, measured by total GDP in US dollars, correlates with estimated market power.[38] We see that large importers have higher degrees of market power. Conditional on country size, we have asserted that importers in remote regions possess added market power over their nearby network of trade partners. Column (2) thus adds a measure of importer remoteness to capture regional market power.[39] We see a stronger correlation between country size and our inverse elasticity as a result, as well as a positive relationship with importer remoteness. Column (2) also controls for physical distance to capture the connectedness of the origin and destination. We see a strong negative relationship between distance and importer market power, suggesting exporters are less responsive to fluctuations in distant markets.

Next, Table 5 investigates whether pairwise relationships between countries within and across goods influence market power. Columns (3) and (4) consider covariates that capture various measures of the share of the imports. We expect that large importers of a particular

[37] Similarly, Caribbean countries (e.g., Jamaica) have the lowest market power across all goods and differentiated goods when we disaggregate. Yet, they have the highest degree of market power over non-differentiated goods. This phenomenon is likely driven by the strong regional trade linkages with other Caribbean countries for non-differentiated goods.

[38] Importer specific measures such as GDP are extracted from *CEPII*. Regressions are based on observations from 2006, which has the most coverage.

[39] Remoteness for country i is defined as $1/\sum_j GDP_j/distance_{ij}$.

good possess greater influence on the world market for that good. In Column (3) we include the importing country's share of total world imports of the HS4 product. Our estimates suggest that going from China's average share of a product's imports (5%) to the US share (16%) implies on average 53% larger inverse export supply elasticities for a given good.

Table 5: Inverse Export Supply Elasticities and Market Size and Share

	$\log(\omega^I_{gv})$					
Controls	(1)	(2)	(3)	(4)	(5)	(6)
log(Importer GDP)	0.045***	0.096***				0.117***
	(0.003)	(0.009)				(0.009)
log(Importer Remoteness)		0.012*				0.016**
		(0.007)				(0.007)
log(Distance)		−0.544***				−0.475***
		(0.006)				(0.006)
Importer's Share of Global Imports of the Product			4.894***			
			(0.129)			
Importer's Share of Total Exporter's Exports Across Products				3.907***		
				(0.073)		
Importer's Share of Exporter's Exports within Product					0.737***	
					(0.035)	
log(Exporter GDP)						−0.435***
						(0.010)
log(Exporter Remoteness)						−0.446***
						(0.008)
R^2	0.067	0.079	0.072	0.073	0.071	0.084
F stat	310.99	4928.98	1438.65	2876.35	450.96	3565.22
N	952384	952384	1042824	1042824	1042824	936503

Notes: All regressions include industry, defined at the HS4 level, fixed effects. Remoteness for country i is defined as $1/\sum_j GDP_j/distance_{ij}$ using data from *CEPII* from 2006. Robust standard errors are in parentheses where, * p<0.10, ** p<0.05, *** p<0.01 indicate significance.

In Column (4) we include the importer's share of the exporter's total trade. This regression demonstrates large importers of a particular exporter's goods have greater market power on average. The heterogeneity of our estimates allow us to look at the finest level of the importer-exporter relationship. Column (5) highlights that even at the most disaggregate level we find intuitive patterns by including the importer's share of the exporter's global exports of the HS4 product. We see that exporters shipping a greater share of a particular product to a particular destination have stronger responses to fluctuations in that market, as they face on average 7.3% larger inverse export supply elasticities for a 10% increase in market share. Lastly, our data allow us to look at characteristics of the exporter and how they may affect importer market power. In Column (6) we include size and remoteness of the exporting country. We see that larger exporters have lower inverse supply elasticities suggesting exporter size can counteract importer market power to some extent.

In what follows, these patterns of market power and their implications for trade policy are used to describe how importers construct tariffs to maximize welfare by exploiting terms of trade gains as policy interacts with market power. The heterogeneity uncovered in the preceding will be shown to provide valuable insight into how importers may set tariffs both theoretically and empirically.

5 Optimal Tariffs

Our analysis of optimal trade policy is related in spirit to Ossa (2014), which calibrates a new trade model to examine the differences between non-cooperative and cooperative trade policies. Notably, his simulations rely on homogenous elasticity estimates (i.e., Feenstra (1994)). Here we estimate the model based on heterogeneity and then evaluate an adapted version of optimal trade policy. Our estimation strategy and evaluation of the theoretical results are perfectly compatible. Ossa (2014)'s analysis is centered around describing the channels of the model under different policy equilibria. Our analysis is data driven, and aimed at presenting a flexible model and estimation technique. We then relate our estimates and predicted optimal policy to the data. The exercise will be to highlight the unique explanatory power provided by heterogeneity on the relationship between applied and optimal non-cooperative tariffs in the data.

Our comparison of optimal and actual trade policy is therefore most closely related to Broda, Limão and Weinstein (2008), who relate optimal non-cooperative tariffs under homogeneity to applied tariffs for a select group of countries. In what follows we thoroughly contrast both methods and how they compare to applied tariffs. Optimal tariffs under heterogeneity are shown to yield avenues for better identification and stronger relationships with applied tariffs than Broda, Limão and Weinstein (2008) through two channels. First, our heterogeneous elasticities reconcile the regularity that large importers tend to have both strong market power and low applied tariffs. This results as heterogeneity implies optimal tariffs depend on the composition of trade.[40] Second, optimal tariff estimates under heterogeneity vary over time with changes in the composition of trade, and thus respond to shifts in importers' trade patterns (e.g., as a result of WTO accession).

The following demonstrates that WTO accession significantly distorts Broda, Limão and Weinstein (2008)'s results. Since optimal tariff estimates under homogeneity do not respond to compositional changes in trade, shifts in the makeup of a country's imports wash away their relationship with applied tariffs. Broda, Limão and Weinstein (2008) and others argue that WTO accession leads to a cooperative policy equilibrium where importers no longer set tariffs related to non-cooperative optimal tariffs. Here we show this is not the case. By accounting for heterogeneity, optimal tariffs adjust with the composition of trade, and a strong link between our optimal and applied tariffs is identified even as trade policy regimes change. This highlights that even when countries are constrained when setting policy (e.g., WTO membership), non-cooperative terms of trade motives (i.e., optimal tariffs) still drive applied tariffs in the data.

One way we think of our results is, introducing heterogeneity in export supply requires our model optimal trade policy to internalize market concentration when constructing tariffs. In this way, our results are related to Ludema and Mayda (2013) who argue that when relating applied tariffs to export supply elasticities for WTO members, controlling for market concentration (they rely on HHIs) is key to identifying terms of trade motives. In our model, the importance of market concentration is borne directly by optimal non-cooperative trade policy (i.e., terms of trade) motives without appeal to a particular bargaining process as in Ludema and Mayda (2013).

Finally, we extend the model to control for Grossman and Helpman (1995) lobbying motives that may drive tariffs observed in the data. Our estimates continue to yield a strong relationship between our optimal and applied tariffs over time and worldwide. Additionally, we augment the data to include bound tariff rates for WTO members. We confirm the predictions of Beshkar, Bond and Rho (2015) and uncover new patterns relating newly

[40] Under homogeneity, the optimal non-cooperative tariff for a given good is the inverse its (homogeneous) export supply elasticity. As a consequence, the optimal tariffs under homogeneity, as in Broda, Limão and Weinstein (2008), do not vary over time.

negotiated bound rates to terms of trade motives in the data.

5.1 Theory

A benevolent social planner will weigh efficiency losses against terms of trade gains when setting tariffs. Generally, the planner will maximize the sum of household income (Y^h) and consumer surpluses (ψ_g), which yields the social welfare function $W = \Sigma_h (Y^h + \Sigma_g \psi_g)$. Consumers in country I obtain utility through their consumption of a numeraire good, denoted c_0^h, and consumption of imported and domestic composites of goods, generally denoted as c_g^h. Utility is given by $U = c_0^h + \Sigma_g u_g(c_g^h)$. This quasilinear structure rules out income effects in the model so that we can focus on trade flows and trade policy. While many factors may influence the relationship between shipped and delivered prices (e.g., exchange rates), we will focus explicitly on the role of tariffs.[41] As such, we can write the delivered price as the shipped price scaled by the tariff, $p_{gv} = (1 + \tau_g^I)p_{gv}^*$. Here we will suppress the importer superscript on prices and quantities for convenience. For now, assume that imported varieties of a particular good are subject to an identical tariff. Specifically, $\tau_{gv}^I = \tau_g^I \; \forall \; v$.[42]

We follow the assumptions laid out by Grossman and Helpman (1994, 1995) to focus the analysis.[43] The numeraire is freely traded in a perfectly competitive market, produced according to constant returns to scale using only labor as an input, and its price is normalized to unity. These assumptions taken together imply unit wages in the economy. Additionally, domestic varieties are produced under constant returns to scale using labor and a specific factor earning quasi-rent π_d. Lastly, tariff revenues are good specific and redistributed uniformly as r_g. Individuals own one unit of labor and a subset of them own at most one unit of industry specific capital.

Normalizing the population to one in conjunction with our assumptions regarding the

[41]Notably, our estimation of import demand and export supply elasticities allowed for, and exploited, other motives that affect prices as they enter through an unobservable error term.

[42]This assumption is not critical for the results. The model can easily be adapted to a setting where importers can set multiple tariffs for a given good. We will make these derivations explicit in the following.

[43]There is a long and storied literature surrounding importer motives to set optimal trade policy dating back to Torrens (1833) and Mill (1874). For a comprehensive discussion of the history of thought see Irwin (1996). For now we focus on the terms of trade motives for policy. Later we will also consider lobbying as a driver of policy as in Grossman and Helpman (1995).

numeraire and utility from Equation (1) yields the social welfare problem,

$$\underset{\tau_g^I}{\operatorname{argmax}} W = 1 + \pi_d + \sum_g \underbrace{\sum_v \tau_g^I p_{gv}^* x_{gv}}_{r_g} + \underbrace{log\left(\left(\sum_v b_{gv}^{\frac{1}{\sigma_g^I}} x_{gv}^{\frac{\sigma_g^I-1}{\sigma_g^I}}\right)^{\frac{\sigma_g^I}{\sigma_g^I-1}}\right) - p_{gv} x_{gv}}_{\psi_g}. \qquad (12)$$

Since worker rents are separable, the above problem amounts to choosing tariffs for each good that balance tariff revenues from terms of trade gains against changes in consumer surplus. Noting the change in consumer surplus with respect to the tariff is $\frac{\partial \psi_g}{\partial \tau_g^I} = -x_{gv} \frac{\partial p_{gv}}{\partial \tau_g^I}$, by the envelope theorem, and $\frac{\partial p_{gv}}{\partial \tau_g^I} = (1+\tau_g^I)\frac{\partial p_{gv}^*}{\partial \tau_g^I} + p_{gv}^*$, from the relation between shipped and delivered prices, the first order condition from (12) is derived for each good as,

$$\sum_v \left(\tau_g^I p_{gv}^* \frac{\partial x_{gv}}{\partial \tau_g^I} - x_{gv} \frac{\partial p_{gv}^*}{\partial \tau_g^I}\right) = 0. \qquad (13)$$

The first term in Equation (13) are the efficiency costs associated with the tariff, as consumers decrease their imports when exporters pass through the cost of the tariff to delivered prices. The second term represents importer terms of trade gains, as exporters partially absorb the tariff in their shipped price. It is intuitive to rewrite the preceding in terms of elasticities with respect to the tariff:

$$\sum_v \left(p_{gv}^* x_{gv} \frac{\partial x_{gv}}{\partial \tau_g^I} \frac{\tau_g^I}{x_{gv}} - p_{gv}^* x_{gv} \frac{\partial p_{gv}^*}{\partial \tau_g^I} \frac{\tau_g^I}{p_{gv}^*} \frac{1}{\tau_g^I}\right) = 0. \qquad (14)$$

Next we simplify Equation (14) given the assumptions of the preceding trade model.[44]

Proposition 1. *The optimal tariff for good g ($\tau_g^{I^*}$) with exporter heterogeneity is,*

$$\tau_g^{I^*} = \frac{\sum_v p_{gv}^* x_{gv} \frac{\omega_{gv}^I}{1+\omega_{gv}^I \sigma_g^I}}{\sum_v p_{gv}^* x_{gv} \frac{1}{1+\omega_{gv}^I \sigma_g^I}} \qquad (15)$$

given our quantitative trade model.

[44]Recall, we have assumed export supply curves are upward sloping of the form $p_{gv}^* = exp(\eta_{gv})(x_{gv})^{\omega_{gv}^I}$. See Appendix D for the full derivation.

Proof. Combining the elasticities of price and quantity with respect to the tariff in our quantitative trade model with Equation (14) yields the importer's welfare-maximizing first-order condition,

$$\sum_v p^*_{gv} x_{gv} \left(\frac{-(1+\overline{\omega}^I_{go}\sigma^I_g)}{(1+\overline{\omega}^I_{go})(1+\omega^I_{gv}\sigma^I_g)} \frac{\tau^I_g}{1+\tau^I_g} + \frac{\omega^I_{gv}(1+\overline{\omega}^I_{go}\sigma^I_g)}{(1+\overline{\omega}^I_{go})(1+\omega^I_{gv}\sigma^I_g)} \frac{\tau^I_g}{1+\tau^I_g} \frac{1}{\tau^I_g} \right) = 0.$$

Rearranging the first-order condition and solving for τ^I_g, yields the welfare maximizing tariff for country I importing good g. □

In essence, the optimal tariff is a trade weighted average of variety-level responses to policy. The numerator represents the total terms of trade gains of the tariff, while the denominator is the total efficiency loss in the industry from the tariff. The social planner thus chooses the tariff that optimally weights the terms of trade gains relative to the efficiency losses by the importance of each of the importer's trading partners. In the canonical case, where the inverse export supply elasticities are homogenous, the planner will set a tariff equal to the common inverse supply elasticity since all varieties yield an identical relationship between terms of trade gains and efficiency losses.[45] Here, the planner takes into account the full distribution of export supply curves along with their interactions with the import demand curve as supply shifts for all varieties in response to a tariff.[46] Put more plainly, when the importer applies an identical tariff across multiple exporters with different export

[45]Trivially, when $\omega^I_{gv} = \omega^I_g$, Equation (15) reduces to $\tau^{I*}_g = \omega^I_g$.

[46]While we have assumed the importer is only able to set a single tariff rate per good, the theory is flexible enough to accommodate any number of tariff rates. For example, suppose the importer divide the varieties of a good into two subsets ($\mathcal{A}$ and $\mathcal{B}$) and set tariffs independently for each (e.g., MFN tariffs set by WTO members). Then there would be two optimal tariffs for the good:

$$\tau^{I^*}_{g\mathcal{A}} = \frac{\sum_{v\in\mathcal{A}} p^*_{gv} x_{gv} \frac{\omega^I_{gv}}{1+\omega^I_{gv}\sigma^I_g}}{\sum_{v\in\mathcal{A}} p^*_{gv} x_{gv} \frac{1}{1+\omega^I_{gv}\sigma^I_g}} \;\forall\; v \in \mathcal{A} \quad \text{and} \quad \tau^{I^*}_{g\mathcal{B}} = \frac{\sum_{v\in\mathcal{B}} p^*_{gv} x_{gv} \frac{\omega^I_{gv}}{1+\omega^I_{gv}\sigma^I_g}}{\sum_{v\in\mathcal{B}} p^*_{gv} x_{gv} \frac{1}{1+\omega^I_{gv}\sigma^I_g}} \;\forall\; v \in \mathcal{B}.$$

This analysis can be extended to any division of the varieties of goods. Also notice the parallel with the homogeneous elasticity case. If the importer perfectly discriminates across varieties (i.e., sets a unique tariff for each imported variety), the optimal tariff is $\tau^{I^*}_{gv} = {p^*_{gv} x_{gv} \omega^I_{gv}/1+\omega^I_{gv}\sigma^I_g}/{p^*_{gv} x_{gv} 1/1+\omega^I_{gv}\sigma^I_g} = \omega^I_{gv}$. Since we never see perfect discrimination in the data, we do not examine this case in the following. However, we will define the optimal tariff across exporters for each tariff rate we see in the data. For example, WTO members setting applying different tariff for other WTO members and non-members will have two optimal tariffs per good across members and non-members. Notably, our results are not sensitive to these assumptions.

supply elasticities, each exporter yields a different terms of trade gain relative to its efficiency loss. The optimal tariff therefore chooses a tariff that optimally weights each exporter's contribution to its total terms of trade gains and efficiency losses.

In contrast to the literature, Ludema and Mayda (2013) argue that market concentration (they rely on HHIs) is important for identifying a relationship between applied tariffs and terms of trade motives when export supply elasticities are homogeneous. To some extent, our optimal tariff internalizes the importance of industry concentration described by Ludema and Mayda (2013). That is to say, introducing exporter heterogeneity bears a resemblance to the channels described in Ludema and Mayda (2013) as it optimally weights each exporter's contribution to terms of trade and efficiency from tariffs. The difference here is that exporter heterogeneity highlights the importance of market composition when setting tariffs even in a non-cooperative policy setting.

5.2 Empirical Evaluation

We next investigate how incorporating export supply heterogeneity into optimal trade policy relates to applied tariffs. The most comparable empirical study to ours is Broda, Limão and Weinstein (2008) (BLW henceforth). BLW demonstrates a strong relationship between applied tariffs and terms of trade gains for select countries when export supply elasticities are homogeneous. We begin our analysis with an apples to apples comparison of our heterogeneous elasticity estimates and the homogenous elasticities from BLW.[47]

5.2.1 Evaluating the Impact of Heterogeneity

For a direct comparison to the literature, start by narrowing the broader sample of countries in this paper to the subset considered by BLW. Table 6 presents summary statistics of the BLW elasticity estimates alongside our heterogeneous elasticities for the subset of countries and years in the narrowed sample. BLW strategically chooses a set of countries at various

[47] The original code and estimates from BLW are available at: https://www.aeaweb.org/aer/data/dec08/20060147_data.zip. Their data include inverse export supply elasticities and applied tariffs across a subset of developing countries and their imported products.

years before significant trade policy regime changes (i.e., WTO accession). Their sample is intended to avoid any effects from structural changes in the policy environment that could convolute the relationship between optimal and applied tariffs. Specifically, they argue that their sample focuses on countries that most likely set tariffs non-cooperatively.

One feature of optimal tariff estimates under homogeneity is that it is constant over time. The following highlights how changes in the composition of trade through WTO accession significantly distorts BLW's results. This result makes it tempting to argue that these countries transitioned from a non-cooperative equilibrium to a cooperative equilibrium in response to joining the WTO. However, we will show that allowing for heterogeneity uncovers that countries still respond to optimal tariffs even after they join the WTO. Briefly, since optimal tariff estimates under homogeneity do not respond to compositional changes in trade, shifts in the makeup of a country's imports over time diminishes their relationship with applied tariffs. Accounting for heterogeneity is pivotal for uncovering the link between applied and optimal tariffs in the wake of compositional shifts in trade.

Table 6: Summary Statistics: Homogeneous and Heterogeneous Export Supply

		Inverse Export Supply Elasticity					Optimal Tariff				
		Heterogeneous		BLW			Heterogeneous		BLW		
Importer	HS4	50^{th}	Mean	50^{th}	Mean	Corr†	50^{th}	Mean	50^{th}	Mean	Corr†
Algeria	739	0.68	68.76	2.96	110.61	0.05	70%	673%	296%	11061%	0.05
Belarus	703	0.78	7.36	1.88	80.15	0.12	78%	168%	188%	8015%	0.18
Bolivia	647	0.79	149.78	2.04	98.58	0.12	81%	998%	204%	9858%	0.14
China	1125	1.30	308.41	2.05	89.02	0.06	119%	2031%	205%	8902%	0.19
Czech Republic	1075	0.75	24.99	1.57	52.74	0.05	76%	135%	157%	5274%	0.16
Ecuador	753	0.77	31.09	2.16	96.30	0.00	79%	195%	216%	9630%	0.08
Latvia	872	0.73	147.19	1.28	53.42	0.07	72%	142%	128%	5342%	0.10
Lebanon	782	0.56	75.76	0.96	57.81	0.01	56%	126%	96%	5781%	0.11
Lithuania	811	0.70	112.36	1.38	63.58	0.04	70%	142%	138%	6358%	0.11
Oman	629	0.65	151.46	1.37	186.33	0.03	61%	346%	137%	18633%	0.11
Paraguay	511	0.86	141.86	3.14	128.30	0.08	81%	726%	314%	12830%	0.14
Russia	1029	0.83	240.20	1.98	47.25	0.03	77%	115%	198%	4725%	0.07
Saudi Arabia	1036	0.58	64.31	1.77	61.57	0.09	59%	120%	177%	6157%	0.16
Taiwan	891	0.52	69.71	1.43	93.74	0.04	63%	122%	143%	9374%	0.05
Ukraine	730	0.81	25.43	2.38	77.45	0.02	82%	160%	238%	7745%	0.07
Full Sample	1207	0.76	126.20	1.78	75.69	0.05	76%	407%	178%	7569%	0.11

Notes: †Corr is the within industry Pearson correlation between the log of the Heterogeneous and BLW estimates. 50^{th} denotes the within importer median. HS4 is the number of imported products in the entire sample.

Table 6 illustrates some key differences between BLW and our heterogeneous estimates.

The optimal tariff is exactly the inverse export supply elasticity in BLW (i.e., under homogeneity). By taking into account the composition of trade, our heterogeneous optimal tariff estimates are orders of magnitude smaller than BLW, even though our average export supply elasticities are about 50% larger. Table 6 illustrates a significant amount of heterogeneity across importers in both the optimal tariff and elasticity estimates that BLW is unable to capture. These differences result in a near zero correlation between our estimated inverse export supply elasticities. The correlation between optimal tariffs predicted by the two models is weakly positive, and about double that of the supply elasticities. These correlation patterns demonstrate that the heterogeneity absorbed by the literature is substantial.

Table 7: Optimal Tariffs: Homogeneous versus Heterogeneous Export Supply

Dependent Variable	Average Tariff at Four-Digit HS (%)							
Fixed Effects	Country				Country and Industry			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Optimal Tariff: BLW	0.0003***				0.0004***			
	(0.0001)				(0.0000)			
Optimal Tariff: $\tau_g^{I^*}$		0.0028***				0.0030***		
		(0.0009)				(0.0008)		
log(Optimal Tariff: BLW)			0.1206***				0.1687***	
			(0.0420)				(0.0407)	
log(Optimal Tariff: $\tau_g^{I^*}$)				0.1560***				0.2306***
				(0.0195)				(0.0210)
Algeria	23.8***	19.8***	23.6***	19.9***	24.6***	19.6***	24.3***	20.0***
	(0.6)	(0.2)	(0.6)	(0.2)	(0.9)	(0.3)	(0.9)	(0.3)
Belarus	12.3***	11.5***	12.2***	11.6***	12.6***	10.3***	12.5***	10.5***
	(0.2)	(0.1)	(0.2)	(0.1)	(0.7)	(0.2)	(0.7)	(0.2)
Bolivia	9.7***	9.5***	9.6***	9.5***	10.1***	8.6***	9.9***	8.9***
	(0.0)	(0.0)	(0.0)	(0.0)	(0.7)	(0.2)	(0.7)	(0.2)
China	37.8***	33.1***	37.7***	33.1***	38.2***	32.4***	38.0***	32.5***
	(0.7)	(0.2)	(0.7)	(0.2)	(0.9)	(0.3)	(0.9)	(0.3)
Czech Republic	9.4***	10.0***	9.3***	10.0***	9.7***	8.8***	9.6***	9.0***
	(0.5)	(0.2)	(0.5)	(0.2)	(0.8)	(0.3)	(0.8)	(0.3)
Ecuador	9.8***	8.3***	9.7***	8.4***	10.3***	7.9***	10.2***	8.1***
	(0.1)	(0.1)	(0.2)	(0.1)	(0.7)	(0.2)	(0.7)	(0.2)
Latvia	7.2***	5.8***	7.2***	5.9***	7.2***	4.4***	7.2***	4.6***
	(0.3)	(0.1)	(0.3)	(0.1)	(0.7)	(0.2)	(0.7)	(0.2)
Lebanon	17.1***	17.7***	17.0***	17.9***	17.1***	15.8***	17.0***	16.2***
	(0.5)	(0.1)	(0.5)	(0.1)	(0.8)	(0.2)	(0.8)	(0.2)
Lithuania	3.6***	3.4***	3.5***	3.5***	3.6***	1.9***	3.5***	2.1***
	(0.2)	(0.1)	(0.2)	(0.1)	(0.7)	(0.2)	(0.7)	(0.2)
Oman	5.6***	5.8***	5.6***	5.9***	5.6***	4.2***	5.6***	4.5***
	(0.3)	(0.1)	(0.3)	(0.1)	(0.7)	(0.3)	(0.7)	(0.3)
Paraguay	16.0***	14.6***	15.9***	14.6***	16.3***	13.2***	16.1***	13.5***
	(0.4)	(0.2)	(0.5)	(0.2)	(0.8)	(0.3)	(0.8)	(0.3)
Russia	10.6***	10.8***	10.5***	10.8***	10.8***	9.1***	10.7***	9.3***
	(0.3)	(0.0)	(0.3)	(0.0)	(0.7)	(0.2)	(0.7)	(0.2)
Saudi Arabia	12.1***	12.2***	12.0***	12.3***	12.4***	10.4***	12.2***	10.8***
	(0.0)	(0.0)	(0.0)	(0.0)	(0.7)	(0.2)	(0.7)	(0.2)
Taiwan	9.6***	9.3***	9.6***	9.4***	10.3***	8.3***	10.1***	8.6***
	(0.2)	(0.0)	(0.2)	(0.0)	(0.7)	(0.2)	(0.7)	(0.2)
Ukraine	7.3***	6.3***	7.2***	6.4***	8.0***	5.4***	7.8***	5.6***
	(0.2)	(0.0)	(0.2)	(0.0)	(0.7)	(0.2)	(0.7)	(0.2)
R^2	0.611	0.612	0.611	0.612	0.660	0.654	0.661	0.654

Notes: Regressions include importer dummies that are labeled by the country name above and industry dummies that are defined by section according the HTS. For the regressions in levels with heterogeneous elasticities, I truncate the estimated optimal tariff at the BLW maximum for comparability. Robust standard errors are in parentheses, where * p<0.10, ** p<0.05, *** p<0.01 indicate significance.

Differences in the distributions of the heterogeneous and homogeneous elasticity estimates extend into our analysis of optimal trade policy. Using the data from BLW, Columns (1), (3), (5) and (7) of Table 7 replicate some of the key results in Table 7 of Broda, Limão and Weinstein (2008).[48] Columns (2), (4), (6) and (8) repeat the study with our estimate of the optimal tariff under heterogeneity. Comparing Columns (1) with (2) and (5) with (6), the relationship between the optimal tariff under heterogeneity and applied tariffs in levels are an order of magnitude larger than the relationship between applied and optimal tariffs under homogeneity.

BLW selected their subsample of countries and years in order to isolate importers' responses to terms of trade motives. They argue that since these countries were yet to join the WTO, they were more likely to target the optimal tariffs without the impediment of the GATT. Our estimates provide strong support for this argument. In the BLW subsample, we find that doubling the optimal tariff leads to about a 0.17 percentage point increase in applied tariffs from Column (7) using BLW's homogeneous elasticities, and a 0.23 percentage point increase from Column (8) using our heterogeneous elasticities.

To investigate whether trade policy regime changes (e.g., WTO accession) affect the ability of countries to respond to terms of trade gains with applied tariffs, we add time series variation to BLW's data. Data on applied tariffs across country pairs over goods are drawn from a combination of *Trains*, the *International Customs Tariffs Bureau* and the WTO.[49] These data span 1991-2007. We combine the data with $CEPII$, which records when countries joined the WTO by signing GATT. Finally, we concord the data to the HS4 level and combine them with *Comtrade*.

Now we can define the number of years since or until an importer joins the WTO. Table 8 regresses applied tariffs on the log of optimal tariffs across various subsamples of the data. Each subsample is defined by years around importers' joining of the WTO. For instance, Column 0 indicates the year of membership, while Column -5^{+} indicates the importer will join in 5 or more years, and Column 3 are importers that have been WTO members

[48]For a full list of years and countries the data are drawn from, see Table 3 in Broda, Limão and Weinstein (2008).

[49]The data were generously furnished by Robert Feenstra and John Romalis. They are the same utilized by Feenstra and Romalis (2014), which include a detailed description in their Appendix B.

for exactly three years. The BLW subsample is best approximated by observations where importers will join the WTO in five or more years (i.e., -5^{+}). This subsample presents the strongest relationship between applied and optimal tariffs, and the coefficient estimates are comparable to Table 7.

Table 8: Optimal Tariffs: The Impact of WTO Membership

	Years Since WTO Accession										
	-5^{+}	-4	-3	-2	-1	0	1	2	3	4	5^{+}
BLW	0.104***	0.047***	0.052***	0.066***	0.059***	0.055***	0.047***	0.046***	0.022***	0.016***	0.014***
	(0.006)	(0.007)	(0.007)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.002)
R^2	0.515	0.473	0.534	0.533	0.546	0.523	0.468	0.400	0.462	0.478	0.536
Obs.	539057	127964	136417	153963	167352	175253	180145	186840	142092	146321	561971
	-5^{+}	-4	-3	-2	-1	0	1	2	3	4	5^{+}
$\tau_g^{I^*}$	0.183***	0.113***	0.100***	0.111***	0.114***	0.114***	0.121***	0.127***	0.152***	0.157***	0.160***
	(0.006)	(0.009)	(0.009)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.009)	(0.008)	(0.004)
R^2	0.515	0.474	0.535	0.533	0.546	0.524	0.469	0.399	0.462	0.475	0.532
Obs.	510347	121597	129695	146679	159674	167399	172168	178584	136990	141109	541376

Notes: Each column regresses applied tariffs on optimal tariffs in the subsample defined by years since WTO accession (superscript $^{+}$ indicates years or more). BLW is the log of the homogeneous optimal tariff. $\tau_g^{I^*}$ is the log of the heterogeneous optimal tariff. All regressions include importer and industry fixed effects. Robust standard errors are in parentheses, where * p<0.10, ** p<0.05, *** p<0.01 indicate significance.

The relationship between applied and BLW optimal tariffs fall precipitously as importers approach WTO accession. In the year that importers join the WTO (Column 0), the estimated relationship is halved when compared to BLW's subset (Column -5^{+}). This relationship continues to decline, and nearly disappears by the time the importer has been a member for more than two years. This result confirms BLW's trepidation in applying their methodology post WTO accession. These results are driven by the fact that both applied tariffs and the composition of trade in countries joining the WTO change rapidly with membership. Since BLW estimates of optimal tariffs under homogeneity are constant over time, they are unable to capture the evolving terms of trade effects over time.

Conversely, our heterogeneous optimal tariffs adjust over time as the composition of trade changes. The estimated relationship between applied and optimal tariffs with heterogeneity in the years preceding WTO membership are strongly positive and over twice the size of the homogeneous optimal tariff estimates. In the years following WTO accession, there is only a slight weakening of the positive estimated relationship between applied and optimal tariffs under heterogeneity. Our heterogenous optimal tariffs adjust to changes in the makeup of trade. This flexibility appears to produce estimates that identify importers responding to terms of trade motives even as the composition of these motives change over time.

This result fits with a burgeoning literature documenting countries' applied tariffs, even in cooperative settings, have enough flexibility to respond to terms of trade motives. The improvement afforded by introducing heterogeneous export supply is we can capture the relationship between terms of trade motives embodied by export supply and applied tariffs predicted by a model of non-cooperative optimal trade policy rather than relying on a particular bargaining structure. In contrast, Ludema and Mayda (2013) argue that including Herfindahl indexes are important for identifying a relationship between applied tariffs and terms of trade motives in the data when export supply elasticities are homogeneous. To some extent, our optimal tariff thus internalizes the role of industry concentration described by Ludema and Mayda (2013).

However, the slight weakening of the estimated relationship between applied and our optimal tariffs at and around WTO accession does support the notion that signing the GATT impedes the ability of importers to adjust tariffs in response to terms of trade gains. BLW specifically suggest an attenuation or elimination in the relationship between the non-cooperative optimal tariff and applied tariffs as a result.[50] Our estimates demonstrate that while WTO membership does seem to attenuate the relationship slightly for this subset of countries, the terms of trade motives for tariff setting do not disappear as homogenous elasticity estimates would suggest. The following investigates the claim that in recent years countries are foregoing the terms of trade motives for setting tariffs in favor of cooperation. We will demonstrate that heterogeneous export supply elasticities are key to uncovering a persistent link between non-cooperative optimal tariffs and applied tariffs in the data.

[50]See Broda, Limão and Weinstein (2008, p. 2061)

5.2.2 Applied and Optimal Tariffs Globally

Preceding results warrant a fully inclusive analysis of the relationship between optimal and applied tariffs. Here we expand the data to the full sample of tariffs and trade flows across all countries over 1991-2007. We will leverage the ability of the heterogeneous estimates to adjust to changes in the composition of trade over time to more extensively study trade policy responses to the terms of trade motives described by our optimal tariff estimates.

Table 9: Summary Statistics: Applied and Optimal Tariffs

	Applied Tariff†			Optimal Tariff ($\tau_g^{I^*}$)		
Importer	Mean	Median	Rank	Mean	Median	Rank
Australia	6.46%	4.66%	13	112.7%	75.6%	17
Brazil	15.55%	14.20%	5	114.1%	74.3%	16
Canada	6.45%	3.40%	14	206.0%	128.3%	7
China & Hong Kong	19.50%	14.15%	2	204.0%	123.7%	8
Germany	5.77%	3.62%	17	141.3%	114.7%	13
France	5.88%	3.75%	15	107.1%	81.5%	19
Great Britain	5.85%	3.68%	16	108.0%	81.3%	18
India	34.99%	30.77%	1	104.4%	70.0%	21
Italy	5.71%	3.62%	20	105.7%	77.6%	20
Japan	5.74%	2.74%	19	157.9%	118.6%	12
Mexico	15.74%	15.25%	4	217.4%	111.7%	6
Russia	11.42%	10.17%	7	122.5%	80.0%	15
United States	4.38%	2.63%	21	140.4%	114.5%	14
African	17.17%	14.23%	3	1070.1%	66.8%	1
Asian	11.10%	7.00%	8	161.4%	63.0%	11
Caribbean	13.84%	15.00%	6	438.5%	86.6%	3
Northern/Western Europe	5.76%	3.39%	18	183.0%	79.3%	10
Oceania	6.84%	4.67%	12	815.7%	78.4%	2
South American	10.66%	10.00%	9	276.4%	74.9%	4
Southern/Eastern Europe	8.81%	8.28%	11	192.6%	79.4%	9
World	10.19%	7.78%	10	262.3%	78.9%	5

Notes: †Applied tariffs are from Feenstra and Romalis (2014) over 1991-2007. For exposition, the top and bottom 0.5% of $\tau_g^{I^*}$ within each country are dropped. Mean is the average within and then across years. Median is the median in the full sample. Rank is the order of the mean from highest to lowest across the listed countries and regions.

Table 9 presents summary statistics of the applied and optimal tariffs across regions in the data. Within sample rankings of the average tariffs are also displayed. Countries setting some of the largest applied tariffs include China, India and Brazil along with African and Caribbean countries. These countries also tend to have large predicted optimal tariffs. More developed countries tend to set much lower tariffs on average. The developed countries setting the lowest tariffs are Italy, Germany, Japan and the US. Surprisingly, even though these countries have the strongest unconditional market power in our estimates (i.e., large average inverse export supply elasticities as highlighted by Table 4), they actually generate some of the lowest predicted optimal tariffs.

This result is unique to the literature. Optimal tariffs estimated under homogeneity are unable to reconcile the low tariffs set by developed countries that also have large estimated average inverse export supply elasticities (i.e., strong market power) without incorporating alternative trade policy motives. Here, this feature of the data is readily explained by the marked heterogeneity across exported varieties mixed with the composition of these varieties consumed by importers. Notably, the magnitudes of our optimal tariff estimates for the full sample are quite similar to recent general equilibrium analysis of optimal tariffs.[51]

Table 10: The Relationship Between Applied and Optimal Tariffs

	Applied Tariff					
Controls	(1)	(2)	(3)	(4)	(5)	(6)
log(Optimal Tariff)	0.227***	0.185***	0.175***	0.122***	0.456***	0.347***
	(0.001)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Exporter WTO				−2.534***		−2.569***
				(0.010)		(0.009)
Importer WTO				−3.825***		−3.863***
				(0.008)		(0.007)
Regional Trade Agreement				−1.771***		−1.720***
				(0.006)		(0.007)
Product FEs	Yes	No	No	No	No	No
Importer FEs	Yes	No	No	No	No	No
ProductXImporter FEs	No	Yes	No	No	No	No
ProductXImporterXExporter FEs	No	No	Yes	Yes	Yes	Yes
R^2	0.412	0.754	0.772	0.784	0.772	0.784
Obs.	18426802	18426802	18426802	16865524	16676470	16579932

Notes: Each column regresses applied tariffs on optimal tariffs under heterogeneity. Importer and Exporter WTO are indicators denoting WTO membership while Regional Trade Agreement indicates a current trade agreement. Fixed effects are denoted as FEs, where product is the HS4 level. The final two columns apply an IV strategy where the optimal tariff weights are instrumented by importer and exporter GDP. Robust standard errors are in parentheses, where * p<0.10, ** p<0.05, *** p<0.01 indicate significance.

[51] Ossa (2014) calibrates a general equilibrium model of optimal tariffs, and calibrates the non-cooperative optimal for his sample to be around 62%, which is comparable to our median estimate across all countries of 78.9%. While the unconditional patterns in the summary statistics are supportive of the predicted link between applied and optimal tariffs, we can establish a more direct link in the data through a series of fixed effect regressions.

Table 10 begins by examining whether the correlations between applied and optimal tariffs established in the previous section are maintained in the full sample. Column (1) regresses applied tariffs on optimal tariffs with only importer and product fixed effects. We see that even in the full sample there is a strong positive relationship between applied and optimal tariffs. Column (2) pushes the data further by including importer-product fixed effects. This specification absorbs any importer-product specific effects that do not vary over time (e.g., constant endogenous lobbying for protection). The coefficient is identified within importers across exporters over time. The estimated relationship remains positive and significant at the 1% level, and is comparable in magnitude to Column (1). Additionally, the explanatory power of the model increases as the adjusted R^2 almost doubles to 0.754.

Our estimates are the first to produce variation over time in the terms of trade motives to set optimal tariffs. Columns (3) and (4) further exploit this variation by controlling for importer by exporter by product fixed effects, such that our estimates are identified solely by variation over time. This strategy has the benefit of absorbing any trade policy targeted at a particular exporter of a given product.[52] Column (3) yields similar results to Column (2) suggesting applied tariffs are mainly determined within importer-product pairs. Still, isolating the variation of tariff changes over time yields a strong positive relationship between applied and optimal tariffs.

Column (4) checks the robustness of Column (3) by including policy regime changes in the form of importers or exporters signing GATT or a regional trade agreement. These regime variables are identified by countries that switch status over time. As we should expect, importers and exporters signing the GATT (i.e., joining the WTO) or a regional trade agreement set lower tariffs. Even after controlling for these regime driven motives of tariff setting there is still a strong positive relationship between applied and optimal tariffs.

Finally, we might be concerned about reverse causality in these regressions as our optimal tariffs are determined using trade share weights within an imported product. Negotiating lower tariffs is often argued to be a product of countries aiming to reduce terms of trade externalities. As such, when tariffs decrease in the data we might expect our optimal tariff

[52] A nice discussion of one such policy is presented by Feenstra and Taylor (2014). Page 233 discusses the 2009 tariffs applied by the US on all tire imports that targeted Chinese exports.

weights to rise for partners with larger inverse export supply elasticities. This would create a mechanical negative correlation between applied and optimal tariffs. Notably, this phenomenon would result in downward bias of our estimates. Even with this downward bias our estimates are positive and significant, and can be thought of as a lower bound for the relationship between applied and optimal tariffs. Nonetheless, we can confront this issue with an instrumental variables approach that borrows from the gravity literature. This literature posits a strong relationship between country sizes (i.e., importer and exporter GDP) and trade flows. We can thus recalculate our optimal tariff replacing the trade weights with importerXexporter GDP to construct a valid instrument for our optimal tariff.[53] Columns (5) - (6) apply this IV approach. We see the estimated coefficient nearly triple, which confirms our expectation that our estimates provide a lower bound for the relationship between applied and optimal tariffs.

In summary, previous studies note the difficulty of identifying terms of trade motives driving tariffs set by WTO members (c.f., Bagwell and Staiger (2011)).[54] Ludema and Mayda (2013) develop a model of cooperative tariff negotiation. They introduce heterogeneity along the dimension of negotiating power. Consequently, they argue that market concentration is an important control when relating terms of trade motives to applied tariffs in the data. The bargaining structure in their model provides tools for uncovering that most favored nations tariffs follow patterns of importer market power. BLW found that US market power influences trade policy only for trade barriers not set cooperatively under the WTO (e.g., non-tariff barriers). Here we find that incorporating heterogeneity into our model of trade transforms the standard measures of market power and terms of trade gains by incorporating the composition of trade. Time series variation in our estimates then allows us a new avenue for identification unavailable to these previous studies that rely on homogeneous elasticities. Controlling for any importer by exporter by good motives driving applied tariffs identifies a strong positive relationship between market power, as embodied by optimal tariffs, and

[53] Explicitly, we instrument for our optimal tariff $\tau_g^{I^*} = \sum_v p^*_{gv} x_{gv} \frac{\omega^I_{gv}}{1+\omega^I_{gv}\sigma^I_g} / \sum_v p^*_{gv} x_{gv} \frac{1}{1+\omega^I_{gv}\sigma^I_g}$ with $\tau_g^{I^{Instrument}} = \sum_v GDP^I * GDP^V \frac{\omega^I_{gv}}{1+\omega^I_{gv}\sigma^I_g} / \sum_v GDP^I * GDP^V \frac{1}{1+\omega^I_{gv}\sigma^I_g}$.

[54] Bagwell and Staiger (2011) argue that tariff reductions by WTO members are geared to mitigate terms of trade motives.

applied tariffs globally. This result persists even after controlling for structural changes in how policy is set through trade agreements such as the GATT and RTAs.

6 Robustness

Here we further examine the relationship between our non-cooperative optimal tariffs and applied tariffs. First, we examine differences in this relationship depending on the duration of importers' WTO membership in the sample. Then we consider alternative motives driving tariffs in the data popularized by the literature. For instance, we conclude by examining the role of domestic lobbying introduced by Grossman and Helpman (1995) on our estimates.

6.1 WTO Status

We have shown that countries respond to non-cooperative tariffs even when we expect them to follow cooperative policies (e.g., via WTO membership). To further examine the role of joining the WTO, we can split our sample into subsets of countries according to their membership, and thereby our expectations of their propensity to follow cooperative policies. We might expect that our preceding results, which pool all countries, are inappropriate for countries that have been WTO members for the entirety of our sample. Table 11 divides the sample into countries that were either always WTO members, never WTO members, or switched status at some point in the sample, and repeats our analysis.

Column (1) presents our preferred specification, Column (4) of Table 10, for reference. We see that countries who have been WTO members for the entire sample (e.g., the US) are less responsive to the terms of trade motives embodied by the optimal tariffs than the full sample. This result is not surprising as we expect these countries to set tariffs more cooperatively. Yet, we still find evidence that there is a significant positive relationship between applied and optimal tariffs even for these countries expected to be in a cooperative equilibrium. Somewhat surprisingly, countries that are yet to join the WTO (e.g., Russia) only slightly set tariffs more aggressively in response to terms of trade motives. We suspect this is partly due to strong regional agreements for these countries, which we can see by the large negative effect of RTAs on applied tariffs.

Countries that switch WTO status in the sample (e.g., China) have an order of magnitude larger relationship between applied and optimal tariffs than the previous groups. This result potentially yields insight into why these countries were targeted to join the WTO. Upon their membership, the coefficient on the interaction of WTO membership and the optimal tariff demonstrates that these switching countries restructure their applied tariffs away from the optimal tariff. These results thus reinforce the notion that the WTO helps to move importers toward a cooperative tariff equilibrium. However, even under the purview of the WTO, countries switching status still follow their optimal tariffs. Notice the net effect of the optimal tariff after they join the WTO is still statistically significant and positive. Our estimates imply that doubling the optimal tariff corresponds with 0.2% larger applied tariffs even after countries join the WTO.

Table 11: The Relationship Between Applied and Optimal Tariffs: WTO Subsets

	Applied Tariff				
WTO Status:	Pooled	Always	Never	Switchers	
Controls	(1)	(2)	(3)	(4)	(5)
log(Optimal Tariff)	0.122***	0.031***	0.042***	0.413***	0.541***
	(0.006)	(0.007)	(0.009)	(0.015)	(0.017)
log(Optimal Tariff)*Importer WTO					−0.368***
					(0.005)
Exporter WTO	−2.534***	−3.347***	−1.988***	−0.087***	−0.106***
	(0.010)	(0.013)	(0.026)	(0.017)	(0.017)
Importer WTO	−3.825***			−4.349***	−4.425***
	(0.008)			(0.009)	(0.009)
Regional Trade Agreement	−1.771***	−2.462***	−3.214***	0.578***	0.581***
	(0.006)	(0.007)	(0.028)	(0.011)	(0.011)
ProductXImporterXExporter FEs	Yes	Yes	Yes	Yes	Yes
R^2	0.784	0.776	0.776	0.776	0.776
Obs.	16865524	11341759	2162337	3361428	3361428
Countries	173	99	38	36	36

Notes: Each column regresses applied tariffs on optimal tariffs under heterogeneity. Fixed effects are denoted as FEs, where product is the HS4 level. Robust standard errors are in parentheses, where * p<0.10, ** p<0.05, *** p<0.01 indicate significance.

Our results provide strong evidence that importers become less responsive to non-cooperative (i.e., terms of trade) motives when setting tariffs following WTO membership. However, they also highlight a strong positive relationship between non-cooperative optimal tariffs and applied tariffs even after WTO membership. This suggests that neglecting non-cooperative motives when evaluating policy even under seemingly cooperative regimes overlooks a substantial channel for tariff setting in the data. Notably, acknowledging exporter heterogeneity was fundamental in identifying this result.

6.2 Bound and Applied Tariff Rates

While we have provided strong evidence that even WTO members apply tariffs in response to terms of trade incentives, it is worth noting that members' ability to change tariffs are constrained. Specifically, WTO members negotiate maximums on applied tariffs that they cannot exceed. These so called bound rates have become of particular interest in the trade policy literature. One such example is Beshkar, Bond and Rho (2015), who analyze how countries will optimally negotiate bound rates and how tariff overhang (i.e., the difference between bound and applied tariffs) depends on the characteristics of the importers and exporters (including importer market power). As we have demonstrated our heterogeneous export supply elasticities and non-cooperative optimal tariffs provide a robust measure of the terms of trade incentives faced by importers. Since our measure of terms of trade varies over time, we can exploit variation in applied tariffs relative to bound tariffs to further examine the channels highlighted in Beshkar, Bond and Rho (2015).

Table 12: Bound Rates and Terms of Trade

	Bound Rate		Bound - Applied		Applied/Bound	
Controls	(1)	(2)	(3)	(4)	(5)	(6)
log(Optimal Tariff)	-0.068^{***}	-0.021^{***}	-0.183^{***}	-0.145^{***}	0.006^{***}	0.011^{***}
	(0.005)	(0.006)	(0.005)	(0.010)	(0.000)	(0.001)
Product FEs	No	Yes	No	Yes	No	Yes
Importer FEs	Yes	Yes	Yes	Yes	Yes	Yes
Exporter FEs	No	Yes	No	Yes	No	Yes
ProductXImporterXExporter FEs	No	Yes	No	Yes	No	Yes
R^2	0.465	0.999	0.415	0.973	0.105	0.785
Obs.	5961300	5961300	5961300	5961300	5961300	5961300

Notes: Regressions of various measures of the bound tariff rate on lags of optimal tariffs under heterogeneity. Fixed effects are denoted as FEs, where product is the HS4 level. Robust standard errors are in parentheses, where * p<0.10, ** p<0.05, *** p<0.01 indicate significance.

After augmenting our worldwide trade data to include all available bound rates from *Trains*, Table 12 follows the empirical specifications in Beshkar, Bond and Rho (2015). Our method provides more flexibility in terms of included fixed effects, but our results broadly confirm each of their main predictions.[55] Columns (5) and (6) add additional evidence for our previous results relating applied to optimal tariffs. We see that even after normalizing applied tariffs by the bound rate for WTO countries, there is a significant positive relationship between applied and optimal tariffs. Combined with the preceding, we have strong evidence that importers are setting applied tariffs in relation to their terms of trade motives conditional on negotiated agreements.

Taking this analysis a step further, we can use our measure of terms of trade incentives to examine the bound rates directly. In general bound rates do not vary much over time. Of the 50,000 or so unique bound goods in our data around 10% change at some point between 1995-2007. Yet, these changes are a result of negotiations between WTO members, and what drives WTO negotiations has been of central importance in the trade policy literature (c.f., Bagwell and Staiger (2011)). Table 13 thus employs our optimal tariff measure, which is uniquely equipped to capture changes in terms of trade incentives, to analyze changes in bound rates.

Table 13: Changes in the Bound Rate and Terms of Trade

	Applied Tariff					
	Pr[ΔBound≠ 0]	ΔBound	ΔBound>0		ΔBound<0	
Controls	(1)	(2)	(3)	(4)	(5)	(6)
log(Optimal Tariff)$_{t-1}$	0.001***	0.003***	0.200***		−0.064***	
	(0.000)	(0.000)	(0.030)		(0.007)	
Δ log(Optimal Tariff)$_{t-1}$				4.646***		0.023
				(1.344)		(0.016)
Product FEs	Yes	No	No	No	No	No
Importer FEs	Yes	Yes	Yes	Yes	Yes	Yes
Exporter FEs	Yes	No	No	No	No	No
ProductXImporterXExporter FEs	Yes	No	No	No	No	No
R^2	0.190	0.000	0.082	0.226	0.051	0.055
Obs.	4928327	4928327	55022	54458	48906	48387

Notes: Regressions of various measures of the bound tariff rate on lags of optimal tariffs under heterogeneity. Fixed effects are denoted as FEs, where product is the HS4 level. Robust standard errors are in parentheses, where * p<0.10, ** p<0.05, *** p<0.01 indicate significance.

[55]Specifically, 1) The bound rate is lower on average when terms of trade effects are high, 2) overhang is lower with in high terms of trade industries and 3) bounds are tighter with high terms of trade.

Column (1) demonstrates that the probability of observing a change in the bound rate is strongly increasing in the level of the optimal tariff. That is to say, bound rates are more likely to be renegotiated when terms of trade incentives are strong. This confirms the predictions of Bagwell and Staiger (2011) directly on the bound rate. In Column (2) we extend the analysis to the magnitude of the negotiated change in the bound rate. We see changes in bound rates are positively related to terms of trade motives. It is conceivable that there are asymmetries in the relationship between our optimal tariff and the change in the bound that depend on whether the negotiation results in a decrease or an increase in the rate. Columns (3) and (4) considers increases and decreases in the bound separately. We see that the bound increases and decreases more in high terms of trade industries.

Lastly, in Columns (5) and (6) we relate changes in the terms trade incentives (i.e., the lagged first difference of our optimal tariff) to changes in the bound. Increases in the bound are estimated to be preceded by increases in the terms of trade incentives across products. Conversely, decreases in the bound seem to be targeted at products with established high terms of trade (Column (4)) but not in response to fluctuations in the terms of trade preceding the negotiation. Our intuition of this result is importers make concessions on the bound rate for goods with stagnant terms of trade in order to negotiate higher bounds in goods with increasing terms of trade motives.[56]

6.3 Protection for Sale

Grossman and Helpman (1995) argue that protectionist trade policy is at least partially motivated by political factors. Here we extend the preceding model of trade policy, which only accounts for terms of trade motives, to allow for endogenous lobbying to influence tariffs. We follow Grossman and Helpman (1995) who allow lobbying to influence the social planner's weighting of importer welfare. To adjust our model, recall importer welfare is given by the sum of consumer income and surplus as $W = \Sigma_h (Y^h + \Sigma_g \psi_g)$. Now assume L organized

[56]The raw data seem to support this bargaining structure as well. We generally observe an increase in the bound of a good accompanied by a decrease in the bound of a different good. Additionally, the distribution across importers changing bound rates is relatively uniform in the number of changes, with no one country responsible for the majority of the changes (China and the US change their bounds most frequently, but are only responsible for 10% of the changes).

lobbies form to represent the specific factor owners in each industry g. These lobbies pay the social planner C_g to represent their interests across industries. With these contributions, the social planner will choose tariffs to maximize the weighted sum of importer welfare and political contributions given by $G \equiv aW + \Sigma_{g \in L} C_g$, where a is the weight the social planner puts on welfare.

Maintaining the preceding functional form assumptions, the optimal tariff with lobbying when countries set tariffs non-cooperatively accounting for exporter heterogeneity is,

$$\tau_g^{I^{*Lobby}} = \frac{\sum_v p^*_{gv} x_{gv} \frac{\omega^I_{gv}}{1+\omega^I_{gv}\sigma^I_g}}{\sum_v p^*_{gv} x_{gv} \frac{1}{1+\omega^I_{gv}\sigma^I_g}} + \frac{I_g - \alpha}{a + \alpha} \frac{z^I_g}{\sigma^I_g}, \tag{16}$$

where I_g indicates whether the industry is politically organized, α is the fraction of voters represented by the lobby, and z^I_g is the inverse of the import penetration ratio in industry g. The relationship between lobbying and protection is thus a consequence of the exposure of domestic producers to import competition (z^I_g) relative to the impact on demand (σ^I_g) from a tariff.

Equation 16 makes clear that the preceding motives for tariffs based on terms of trade heterogeneity remain in tact regardless of the degree of lobbying. However, if we think lobbying plays an important role in the formation of tariffs, our preceding regressions may suffer from omitted variable bias even when we include product-importer-exporter fixed effects as import penetration varies over time. The hurdle when taking Equation 16 to data is the paucity of reliable measures of import penetration at disaggregate levels for many countries since domestic production is rarely documented. The most thorough dataset recording domestic production that fits our data requirements is the *Trade Protection and Production* (TPP) database, which was developed by Nicita and Olarreaga (2007) and is partially extracted from *UNIDO*. After combining the TPP with our estimates and import data, we are left with 96 importers across 153 HS4 industries from 1991-2003. These data have greater coverage for developed countries, but do contain a number of developing countries.[57]

Domestic production data allow us to construct z^I_g for each importer in the data, which

[57]In terms of coverage, the US, UK and Japan have the most while Yuganda and Nepal have the least.

we divide by our estimates of σ_g^I to form our measure of the impact of lobbying. Table 14 first establishes that our terms of trade measure (which we will continue to call the optimal tariff) is positively correlated with applied tariffs in this subsample after controlling for importer and product fixed effects. The estimated coefficient in this subsample where we have domestic production data is about half the size of the preceding, but still positive and significant.

Table 14: Applied and Optimal Tariffs with Protection for Sale

	Applied Tariff			
Controls	(1)	(2)	(3)	(4)
log(Optimal Tariff)	0.077***	0.108***	0.102***	0.102***
	(0.026)	(0.026)	(0.027)	(0.027)
$log\left(\frac{z^I}{\sigma_g^I}\right)$		0.928***	0.901***	0.852***
		(0.010)	(0.011)	(0.011)
Exporter WTO				−1.611***
				(0.045)
Importer WTO				−1.126***
				(0.027)
Regional Trade Agreement				−1.678***
				(0.025)
Product FEs	Yes	Yes	Yes	Yes
Importer FEs	Yes	Yes	Yes	Yes
Exporter FEs	No	No	Yes	Yes
ProductXImporter FEs	Yes	Yes	No	No
ProductXImporterXExporter FEs	No	No	Yes	Yes
R^2	0.869	0.871	0.882	0.883
F-Statistic	8.73	4198.04	3678.93	3433.15
Obs.	933115	933115	933115	918951

Notes: Each column regresses applied tariffs on optimal tariffs under heterogeneity. Fixed effects are denoted as FEs, where product is the HS4 level. Robust standard errors are in parentheses, where * p<0.10, ** p<0.05, *** p<0.01 indicate significance.

Column (2) of Table 14 introduces our lobbying measure. After controlling for lobbying motives, the estimated coefficient on the optimal tariff increases significantly. The lobbying coefficient on $log({}^{z^I}/{}_{\sigma_g^I})$ is positive and significant as expected. The identification strategy above relied on absorbing product-importer-exporter effects. Column (3) applies this procedure so that the estimated coefficients are identified by variation over time. Our estimates are relatively unchanged, and both optimal tariffs and lobbying have a positive relationship with applied tariffs. Finally, Column (4) includes controls for WTO membership and regional trade agreements. These cooperative policies all enter the regression with negative significant coefficients, as expected. Our terms of trade and lobbying motives have a persistent positive relationship with applied tariffs.

As others have demonstrated, we could delve deeper into these political economy motives empirically (c.f., Goldberg and Maggi (1999) and Bombardini (2008)). However the focus here is highlighting that our estimated terms of trade motives strongly relate to tariffs set in the data. Our results demonstrate that these motives are robust to, and even strengthened by, controlling for political economy motives. Additionally, introducing heterogeneity has provided us with unique tools to identify the relationship between both terms of trade and political economy motives with applied tariffs in the data over time.

7 Conclusion

After adapting a quantitative model of trade and trade policy to incorporate exporter and importer heterogeneity, we construct a flexible structural estimator of the underlying heterogeneous export supply and import demand elasticities. The estimates produce intuitive relationships with expected patterns of importer and exporter market power. Our estimates and theory imply a new measure for the optimal tariff set by an importer. These optimal tariffs are strongly correlated with applied tariffs across a plethora of dimensions of the data. Additionally, the rich detail of the estimates and theory allow us to meaningfully decompose the channels of tariff setting across countries and products. Amongst other things, the data display intuitive patterns of importers targeting goods that generate pronounced terms of trade gains with higher tariff rates.

The unmatched degree of heterogeneity in the trade elasticity estimates produced here opens new avenues to deepening our understanding of a host of prominent theories. Supply elasticities are fundamental to evaluating core channels of globalization such as the degree of passthrough between countries (as in Goldberg and Knetter (1997)) and our estimates of trade indexes (restrictiveness as in Anderson and Neary (1996) and prices as in Feenstra (1994)). The tractability of the estimator constructed in this paper lends itself naturally to extending these prevailing theories of inter-country relationships to include heterogeneity.

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For Online Publication: Appendix

A Derivation of Estimating Equations

A.1 Importer Demand

Demand for any variety of imported good g in country I is given by,

$$x_{gvt}^{I\leftarrow V} = \left(\frac{p_{gvt}^{I\leftarrow V}}{\mathcal{P}_{gt}^{I}}\right)^{1-\sigma_g^I} \frac{b_{gvt}^{I} E_{gt}^{I}}{p_{gvt}^{I\leftarrow V}},$$

which leads to *within* destination market shares of the form,

$$s_{gvt}^{I\leftarrow V} = \frac{p_{gvt}^{I\leftarrow V} x_{gvt}^{I\leftarrow V}}{\sum_v p_{gvt}^{I\leftarrow V} x_{gvt}^{I\leftarrow V}} = \frac{\left(\frac{p_{gvt}^{I\leftarrow V}}{\mathcal{P}_{gt}^{I}}\right)^{1-\sigma_g^I} b_{gvt}^{I} E_{gt}^{I}}{E_{gt}^{I}} = \left(\frac{p_{gvt}^{I\leftarrow V}}{\mathcal{P}_{gt}^{I}}\right)^{1-\sigma_g^I} b_{gvt}^{I}$$

First we take logs to simplify the algebra. Then we first difference shares (denoted Δ) to eliminate time specific unobservables,

$$\Delta log(s_{gvt}^{I\leftarrow V}) = \varphi_{gt}^{I} + \left(1-\sigma_g^I\right)\Delta log(p_{gvt}^{I\leftarrow V}) + \Delta log(b_{gvt}^{I}),$$

where $\varphi_{gt}^{I} = \left(\sigma_g^I - 1\right)\Delta\mathcal{P}_{gt}^{I}$. Note that the above still contains good specific unobservables $\left(\varphi_{gt}^{I}\right)$. Thus, we select a reference variety k (i.e., a variety exported from ^{K} to ^{I}) and difference once more (denote reference differences by superscript k) which yields,

$$\Delta^k log(s_{gvt}^{I\leftarrow V}) = \left(1-\sigma_g^I\right)\Delta^k log(p_{gvt}^{I\leftarrow V}) + \epsilon_{gvt}^{I} \quad (17)$$

where $\epsilon_{gvt}^{I} = \Delta log(^{b_{gvt}^{I}}/_{b_{gkt}^{I}})$ are first and reference differenced unobservable variety specific taste shocks.

A.2 Exporter Supply

Given monopolistically competitive exporters we can write exporter V's share of total export supply as,

$$s_{gvt}^{I\leftarrow V} = \frac{p_{gvt}^{I\leftarrow V} x_{gvt}^{I\leftarrow V}}{\sum_v p_{gvt}^{I\leftarrow V} x_{gvt}^{I\leftarrow V}} = \frac{\left(p_{gvt}^{I\leftarrow V}\right)^{\frac{\omega_{gv}^{I}+1}{\omega_{gv}^{I}}} exp\left(\frac{-\eta_{gvt}^{I}}{\omega_{gv}^{I}}\right)}{\sum_v \left(p_{gvt}^{I\leftarrow V}\right)^{\frac{\omega_{gv}^{I}+1}{\omega_{gv}^{I}}} exp\left(\frac{-\eta_{gvt}^{I}}{\omega_{gv}^{I}}\right)}$$

We follow the same approach as before and first difference to obtain,

$$\Delta log(s^{I\leftarrow V}_{gvt}) = \psi^I_{gt} + \frac{\omega^I_{gv}+1}{\omega^I_{gv}}\Delta log(p^{I\leftarrow V}_{gvt}) + \Delta\frac{\eta^I_{gvt}}{\omega^I_{gv}},$$

where $\psi^I_{gt} = \Delta log\left(\sum_v \left(p^{I\leftarrow V}_{gvt}\right)^{\frac{\omega^I_{gv}+1}{\omega^I_{gv}}} exp\left(\frac{-\eta^I_{gvt}}{\omega^I_{gv}}\right)\right)$. Then, to eliminate good specific unobservables (ψ^I_{gt}) we select the same variety k as above and difference. This yields,

$$\Delta^k log(s^{I\leftarrow V}_{gvt}) = \frac{\omega^I_{gv}+1}{\omega^I_{gv}}\Delta log(p^{I\leftarrow V}_{gvt}) - \frac{\omega^I_{gk}+1}{\omega^I_{gk}}\Delta log(p^{I\leftarrow K}_{gkt}) + \rho^I_{gvt}, \tag{18}$$

where $\rho^I_{gvt} = \Delta\frac{\eta^I_{gvt}-\eta^I_{gkt}}{\omega^I_{gv}}$ are first and reference differenced unobservable supply shocks.

A.3 Estimating Equation: Importer Perspective

Assuming supply and demand shocks are uncorrelated, we can multiply the residuals from supply and demand for the importer to generate the following estimating equation,

$$\begin{aligned}\rho^I_{gvt}\epsilon^I_{gvt} =&\Delta^k log(s^{I\leftarrow V}_{gvt})^2 - (1-\sigma^I_g)\Delta^k log(s^{I\leftarrow V}_{gvt})\Delta^k log(p^{I\leftarrow V}_{gvt}) - \frac{\omega^I_{gv}+1}{\omega^I_{gv}}\Delta^k log(s^{I\leftarrow V}_{gvt})\Delta log(p^{I\leftarrow V}_{gvt})\\ &+ \frac{\omega^I_{gk}+1}{\omega^I_{gk}}\Delta^k log(s^{I\leftarrow V}_{gvt})\Delta log(p^{I\leftarrow K}_{gkt}) + \frac{(\omega^I_{gv}+1)(1-\sigma^I_g)}{\omega^I_{gv}}\Delta^k log(p^{I\leftarrow V}_{gvt})\Delta log(p^{I\leftarrow V}_{gvt})\\ &- \frac{(\omega^I_{gk}+1)(1-\sigma^I_g)}{\omega^I_{gk}}\Delta^k log(p^{I\leftarrow V}_{gvt})\Delta log(p^{I\leftarrow K}_{gkt}).\end{aligned}$$

Simplifying and solving for $\Delta^k log(p^{I\leftarrow V}_{gvt})^2$ we obtain

$$\begin{aligned}\Delta^k log(p^{I\leftarrow V}_{gvt})^2 =&\frac{\omega^I_{gv}}{(1+\omega^I_{gv})(\sigma^I_g-1)}\Delta^k log(s^{I\leftarrow V}_{gvt})^2 + \frac{\omega^I_{gv}}{1+\omega^I_{gv}}\Delta^k log(s^{I\leftarrow V}_{gvt})\Delta^k log(p^{I\leftarrow V}_{gvt})\\ &- \frac{1}{\sigma^I_g-1}\Delta^k log(s^{I\leftarrow V}_{gvt})\Delta log(p^{I\leftarrow V}_{gvt}) + \frac{\omega^I_{gv}(1+\omega^I_{gk})}{\omega^I_{gk}(1+\omega^I_{gv})(\sigma^I_g-1)}\Delta^k log(s^{I\leftarrow V}_{gvt})\Delta log(p^{I\leftarrow K}_{gkt})\\ &+ \frac{\omega^I_{gv}-\omega^I_{gk}}{\omega^I_{gk}(1+\omega^I_{gv})}\Delta^k log(p^{I\leftarrow V}_{gvt})\Delta log(p^{I\leftarrow K}_{gkt}) + u^I_{gvt},\end{aligned} \tag{19}$$

where $E[u^I_{gvt}] \equiv E\left[\frac{\omega^I_{gv}\rho^I_{gvt}\epsilon^I_{gvt}}{(1+\omega^I_{gv})(\sigma^I_g-1)}\right] = 0$. As described in the text, we can estimate Equation (19) using the 2SLS procedure described by Feenstra (1994), which maps the data into hyperbolae, but cannot identify the export supply elasticities.

A.4 Exporter Demand

To achieve identification, we need to follow a similar procedure as above from the exporter's perspective. For any good g and exporter V, demand for variety v in destination I is given by,

$$x^{V\rightarrow I}_{gvt} = \left(\frac{p^{V\rightarrow I}_{gvt}}{\mathcal{P}^I_{gt}}\right)^{1-\sigma^I_g}\frac{b^I_{gvt}E^I_{gt}}{p^{V\rightarrow I}_{gvt}},$$

which leads to *across* destination market shares of the form,

$$s^{V\rightarrow I}_{gvt} = \frac{p^{V\rightarrow I}_{gvt}x^{V\rightarrow I}_{gvt}}{\sum_I p^{V\rightarrow I}_{gvt}x^{V\rightarrow I}_{gvt}} = \frac{\left(\frac{p^{V\rightarrow I}_{gvt}}{\mathcal{P}^I_{gt}}\right)^{1-\sigma^I_g} b^I_{gvt}E^I_{gt}}{\sum_I\left(\frac{p^{V\rightarrow I}_{gvt}}{\mathcal{P}^I_{gt}}\right)^{1-\sigma^I_g} b^I_{gvt}E^I_{gt}} = \left(\frac{p^{V\rightarrow I}_{gvt}}{\mathcal{P}^I_{gt}}\right)^{1-\sigma^I_g}\frac{b^I_{gvt}E^I_{gt}}{X^V_{gvt}}.$$

Taking logs and first differencing yields,

$$\Delta log(s^{V\rightarrow I}_{gvt}) = \Delta log\left(\frac{E^I_{gt}}{X_{gvt}}\right) + \left(\sigma^I_g-1\right)\Delta log(\mathcal{P}^I_{gt}) + \left(1-\sigma^I_g\right)\Delta log(p^{V\rightarrow I}_{gvt}) + \Delta log(b^I_{gvt})$$

To eliminate exporter specific effects $\left(X^V_{gvt}\right)$, we choose a reference destination J and difference to obtain

$$\Delta^j log(s^{V\rightarrow I}_{gvt}) = \left(1-\sigma^I_g\right)\Delta log(p^{V\rightarrow I}_{gvt}) - \left(1-\sigma^J_g\right)\Delta log(p^{V\rightarrow J}_{gvt}) + \epsilon^V_{gvt}, \tag{20}$$

where $\epsilon^V_{gvt} = \Delta log\left(\frac{b^I_{gvt}}{b^J_{gvt}}\frac{E^I_{gt}}{E^J_{gt}}\frac{(\mathcal{P}^I_{gt})^{\sigma^I_g-1}}{(\mathcal{P}^J_{gt})^{\sigma^J_g-1}}\right)$ are first and reference differenced unobservable demand shocks.

A.5 Exporter Supply

The share of total export supply from country V to country I is given by,

$$s_{gvt}^{V\to I}=\frac{p_{gvt}^{V\to I}x_{gvt}^{V\to I}}{\sum_I p_{gvt}^{V\to I}x_{gvt}^{V\to I}}=\frac{\left(p_{gvt}^{V\to I}\right)^{\frac{\omega_{gv}^I+1}{\omega_{gv}^I}}exp\left(\frac{-\eta_{gvt}^I}{\omega_{gv}^I}\right)}{\sum_I\left(p_{gvt}^{V\to I}\right)^{\frac{\omega_{gv}^I+1}{\omega_{gv}^I}}exp\left(\frac{-\eta_{gvt}^I}{\omega_{gv}^I}\right)}.$$

Taking logs and first differencing yields

$$\Delta log(p_{gvt}^{V\to I})=\psi_{gt}^V+\frac{\omega_{gv}^I}{\omega_{gv}^I+1}\Delta log(s_{gvt}^{V\to I})+\Delta\frac{\eta_{gvt}^I}{\omega_{gv}^I},$$

where $\psi_{gt}^V=\Delta log\left(\sum_I\left(p_{gvt}^{V\to I}\right)^{\frac{\omega_{gv}^I+1}{\omega_{gv}^I}}exp\left(\frac{-\eta_{gvt}^I}{\omega_{gv}^I}\right)\right)$. To eliminate exporter specific effects, we choose the same reference destination J as above and difference to obtain,

$$\Delta^j log(p_{gvt}^{V\to I})=\frac{\omega_{gv}^I}{\omega_{gv}^I+1}\Delta log(s_{gvt}^{V\to I})-\frac{\omega_{gv}^J}{\omega_{gv}^J+1}\Delta log(s_{gvt}^{V\to J})+\rho_{gvt}^V, \tag{21}$$

where $\rho_{gvt}^V=\Delta\frac{\eta_{gvt}^I-\eta_{gvt}^J}{\omega_{gv}^I+1}$ are first and reference differenced unobserved supply shocks. Here it is worth noting that while we are allowing export supply shocks to be destination specific, we make the intuitive assumption that the difference between the first differenced supply shocks in two destinations is zero in expectation. Specifically, assume $\mathrm{E}[\Delta\eta_{gvt}^I-\eta_{gvt}^J]=0$.

A.6 Estimating Equation: Exporter Perspective

Assuming supply and demand shocks are uncorrelated, we multiply the residuals from supply and demand for the exporter to generate the following estimating equation

$$\begin{aligned}\rho_{gvt}^V\epsilon_{gvt}^V=&\left(\sigma_g^I-1\right)\Delta log(p_{gvt}^{V\to I})^2-\left(1-\sigma_g^J\right)\Delta log(p_{gvt}^{V\to J})^2-\frac{\omega_{gv}^I}{\omega_{gv}^I-1}\Delta log(s_{gvt}^{V\to I})^2\\&-\frac{\omega_{gv}^J}{\omega_{gv}^J+1}\Delta log(s_{gvt}^{V\to J})^2+\left(1-\left(\sigma_g^I-1\right)\frac{\omega_{gv}^I}{\omega_{gv}^I+1}\right)\Delta log(p_{gvt}^{V\to I})\Delta log(s_{gvt}^{V\to I})\\&-\left(1-\left(\sigma_g^I-1\right)\frac{\omega_{gv}^J}{\omega_{gv}^J+1}\right)\Delta log(p_{gvt}^{V\to I})\Delta log(s_{gvt}^{V\to J})+\left(1-\left(\sigma_g^J-1\right)\frac{\omega_{gv}^I}{\omega_{gv}^I+1}\right)\Delta log(p_{gvt}^{V\to J})\Delta log(s_{gvt}^{V\to I})\\&-\left(1-\left(\sigma_g^J-1\right)\frac{\omega_{gv}^J}{\omega_{gv}^J+1}\right)\Delta log(p_{gvt}^{V\to J})\Delta log(s_{gvt}^{V\to J})+\left(\frac{\omega_{gv}^I}{\omega_{gv}^I+1}+\frac{\omega_{gv}^J}{\omega_{gv}^J+1}\right)\Delta log(s_{gvt}^{V\to I})\Delta log(s_{gvt}^{V\to J})\\&-\left(\left(\sigma_g^I-1\right)+\left(\sigma_g^J-1\right)\right)\Delta log(p_{gvt}^{V\to I})\Delta log(p_{gvt}^{V\to J})\end{aligned}$$

Simplifying and solving for $\Delta log(p_{gvt}^{I\leftarrow V})^2$ after adding $\Delta log(p_{gvt}^{J\leftarrow V})^2$ to both sides, we obtain

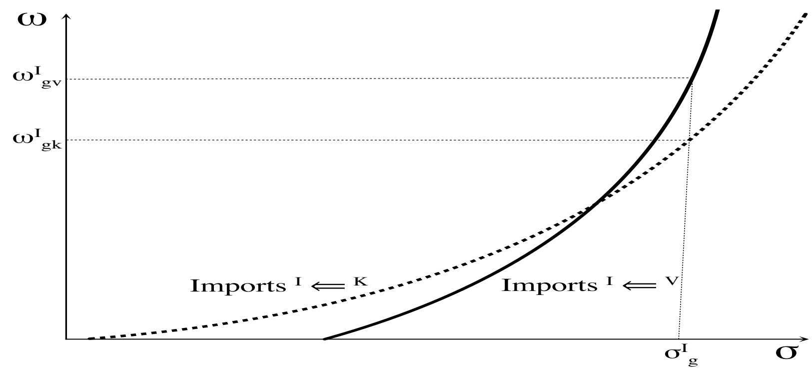
$$\begin{aligned}\Delta^j log(p_{gvt}^{V\to I})^2=&\frac{\omega_{gv}^I}{(1+\omega_{gv}^I)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to I})^2+\frac{\omega_{gv}^I(\sigma_g^I-2)-1}{(1+\omega_{gv}^I)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to I})\Delta log(p_{gvt}^{V\to I})\\&+\frac{\omega_{gv}^J}{(1+\omega_{gv}^J)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to J})^2+\frac{1-\omega_{gv}^J(\sigma_g^I-2)}{(1+\omega_{gv}^J)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to J})\Delta log(p_{gvt}^{V\to I})\\&+\frac{1-\omega_{gv}^J(\sigma_g^J-2)}{(1+\omega_{gv}^J)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to J})\Delta log(p_{gvt}^{V\to J})+\frac{\omega_{gv}^I(\sigma_g^J-2)-1}{(1+\omega_{gv}^I)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to I})\Delta log(p_{gvt}^{V\to J})\\&-\frac{\omega_{gv}^J(1+\omega_{gv}^I)+\omega_{gv}^I(1+\omega_{gv}^J)}{(1+\omega_{gv}^I)(1+\omega_{gv}^J)(\sigma_g^I-1)}\Delta log(s_{gvt}^{V\to I})\Delta log(s_{gvt}^{V\to J})+\frac{\sigma_g^I-\sigma_g^J}{\sigma_g^I-1}\Delta log(p_{gvt}^{V\to J})^2\\&+\frac{\sigma_g^J-\sigma_g^I}{\sigma_g^I-1}\Delta log(p_{gvt}^{V\to J})\Delta log(p_{gvt}^{V\to I})+u_{gvt}^V,\end{aligned} \tag{22}$$

where $E[u_{gvt}^V]\equiv E\left[\rho_{gvt}^V\epsilon_{gvt}^V/\sigma_g^I-1\right]=0$, as supply and demand shocks are independent and the expected difference between supply shocks within an exporter across destinations is zero. Again, we estimate Equation (22) using the 2SLS procedure described by Feenstra (1994), which maps the data into hyperbolae. By combining Equations (19) and (22) we can consistently identify all supply and demand elasticities in the data.

B Identification: A discussion

With demand and supply in the importing country specified, we can begin discussing estimation. Feenstra (1994) developed a methodology to consistently estimate the above system if we are willing to assume homogeneous export elasticities (i.e., $\omega_{gv}^{I} = \omega_{g}^{I} \ \forall \ v$). The estimator is based on Leamer (1981) and Feenstra (1994).[58] Briefly, Leamer (1981) asserts that with time-series variation in a variety's prices and shares, we can construct a hyperbola containing the true elasticities.[59] Even though OLS estimates of our elasticities are biased, Leamer (1981) demonstrates the variation in the data combined with OLS estimates contain information. He shows how if we knew one elasticity for certain we could uniquely solve for the other as a point on the hyperbola. Feenstra (1994) establishes that if a country imports at least two varieties the intersection(s) of the hyperbolae can be used to consistently estimate supply and demand elasticities based on this intuition.

Figure A1: Importer Hyperbolae



The intuition for the estimator is best seen in a picture. Figure A1 plots a hypothetical importer of two varieties supposing we know the true import demand and export supply elasticities. The true demand elasticity is indicated by σ_{g}^{I}, and the true export supply elasticity of the variety from country V destined for country I is ω_{gv}^{I}.[60] By assuming that import demand and export supply elasticities are homogenous across varieties, Feenstra (1994) demonstrates that the intersection of the hyperbolae depicted in Figure A1 would uniquely identify each elasticity. Here, heterogeneous export supply elasticities imply that the intersection of hyperbolae no longer characterizes the solution, and the system of Equations (5) and (6) cannot solely identify the elasticities. Identification is thus the fundamental issue generated by allowing for pairwise heterogeneity.

Figure A2 is the exporter market analog to Figure A1 for good g. Hypothetical *exporter* hyperbolae implied by Equations (8) and (9) are presented assuming we know the true elasticities as in Figure A1. Notably, the import demand elasticity σ_{g}^{I} and export supply elasticity ω_{gv}^{I} are the same as those presented in Figure A1.

Again, we could apply the intuition of Feenstra (1994) discussed above, but we would end with an analogous conclusion. Export flows, as with import flows, cannot uniquely identify heterogeneous elasticities on their own. However, the statistical differences between market shares within versus across destinations

[58] Soderbery (2015) provides a thorough discussion of the methodology.

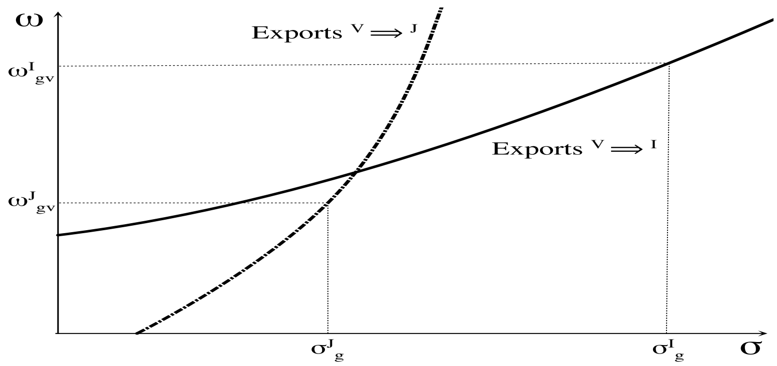
[59] Leamer (1981) demonstrates hyperbolae from a time series of price and quantity data are defined as:

$$(\beta - \tfrac{cov(p,x)}{var(p)})(\Theta - \tfrac{cov(p,x)}{var(p)}) = \left(\tfrac{cov(p,x)^2}{var(x)var(p)} - 1\right)\left(\tfrac{var(x)}{var(p)}\right)$$

where Θ is the true supply elasticity and β is the true demand elasticity.

[60] The true export supply elasticity of the good from country K destined for country I is ω_{gk}^{I}.

Figure A2: Exporter Hyperbolae



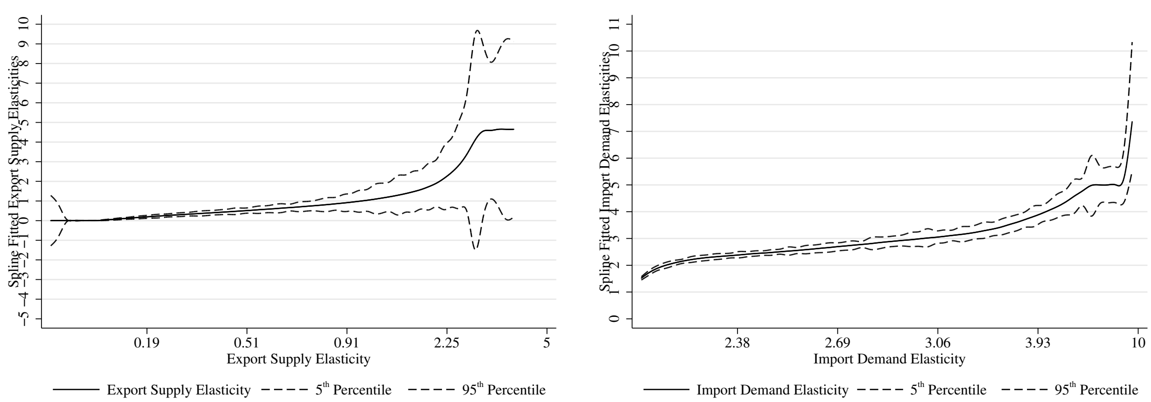
will be key for identification. Notice that shares from both the exporter and importer perspective are derived from the same fundamental elasticities, but are generated by structurally different shock processes.

C Standard Errors of our Estimated Elasticities

Given the millions of elasticities estimated in this paper, line by line discussion of standard errors is infeasible. Additionally, the computational rigor of the estimation procedure makes standard bootstrap confidence intervals across the full set of estimates infeasible. However, our estimation routine does provide robust standard errors. While these are likely imperfect measures as they do not account for the truncated nature of the estimator, they provide some sense of the variability of our estimates.

Presentation of these estimated standard errors is a challenge given the sheer number of estimates. What we do in the following is construct the 95% confidence interval for every estimated elasticity implied by its estimated standard error. Figure A3 then plots the point estimates and uses a spline regression through the estimated bounds of the confidence intervals to construct a median best fit 95% confidence interval for the universe of our estimates.

Figure A3: Elasticity Estimates and Confidence Intervals



The leftmost figure plots our estimated ω_{gv}^Is. The solid line are the point estimates, and the dashed lines form our 95% confidence interval. The horizontal axis is divided into quintiles. To be clear, the figure demonstrates that around 20% of our estimated inverse export supply elasticities lie between 0.51 and 0.91. We can thus see that the majority of our estimated elasticities (the range between 0.05 and 2.25 or around 90% of our estimates) are statistically significantly greater than zero and fairly precisely estimated. As we might expect, there is more variation in our estimates as we approach the tails. This analysis is also echoed by our estimates import demand elasticities as seen in the rightmost figure.

D Optimal Tariff Derivation

Clearing the import and export market implies the equilibrium shipped price of variety v:[61]

$$p^*_{gv} = \left(\varphi_{gv}(1+\tau^I_g)^{-\sigma^I_g}\mathcal{P}_g^{\sigma^I_g-1}\right)^{\frac{\omega^I_{gv}}{1+\omega^I_{gv}\sigma^I_g}}. \tag{23}$$

The term $\varphi_{gv} \equiv \frac{\xi^I_X \phi^I_g b_{gv}}{exp(-\eta_{gv}/\omega^I_{gv})}$ is comprised of unobservable variety-specific characteristics that are independent of the tariff. Solving for the aggregate price level allows us to represent each exported variety's price as a function of tariffs. To do so, we aggregate the individual variety prices given by the market clearing condition in (23) to match the CES price index. This aggregation yields,

$$\mathcal{P}_g = (1+\tau^I_g)^{\frac{1}{1+\overline{\omega}^I_{go}}}\Phi_g. \tag{24}$$

In order to aggregate prices, we must define an "average" variety that charges a price equal to the price index. Let this average variety be produced with technology denoted $\overline{\omega}^I_{go}$.[62] The term Φ_g is an index of variety taste and technology parameters, which is unaffected by the tariff.[63]

Combining the price index with the market clearing price in (23) yields the price charged by variety v in terms of the tariff,

$$p^*_{gv} = (1+\tau^I_g)^{\frac{-\omega^I_{gv}(1+\overline{\omega}^I_{go}\sigma^I_g)}{(1+\overline{\omega}^I_{go})(1+\omega^I_{gv}\sigma^I_g)}}\left(\varphi_{gv}\Phi_g^{\sigma^I_g-1}\right)^{\frac{\omega^I_{gv}}{1+\omega^I_{gv}\sigma^I_g}}.$$

Heterogeneity in export supply elasticities drive differential price responses to the tariff across the imported varieties.[64] Additionally, we can write imports as a function of the tariff and variety-specific characteristics,

$$x_{gv} = (1+\tau^I_g)^{\frac{-(1+\overline{\omega}^I_{go}\sigma^I_g)}{(1+\overline{\omega}^I_{go})(1+\omega^I_{gv}\sigma^I_g)}} exp(-\eta_{gv})\left(\varphi_{gv}\Phi_g^{\sigma^I_g-1}\right)^{\frac{1}{1+\omega^I_{gv}\sigma^I_g}}.$$

Again, we can see the significance of heterogeneity in export supply elasticities on variety-level adjustments to trade in response to tariff changes.[65] These heterogenous responses will be key to a country's determination of optimal trade policy. With heterogeneity, the importer will measure the relative welfare contributions of each variety when setting tariffs.

D.1 Price Index Derivation

Recall that $\mathcal{P}_g = \left(\sum_v b_{gv} p_{gv}^{1-\sigma^I_g}\right)^{\frac{1}{1-\sigma^I_g}}$ is the standard CES price index. We need to transform then aggregate the individual variety prices given by the market clearing condition. First transform the market clearing

[61]The market clearing condition equates import demand with export supply curves and is given by $\xi^I_X \phi^I_g b_{gv} p_{gv}^{-\sigma^I_g}\mathcal{P}_g^{\sigma^I_g-1} = (exp(-\eta_{gv})p^*_{gv})^{1/\omega^I_{gv}}$.

[62]The exact value of $\overline{\omega}^I_{go}$ is irrelevant to the calculation of the optimal tariff, but should be thought of as the within good import weighted geometric mean of the heterogeneous export supply elasticities ω^I_{gv}.

[63]Explicitly, $\Phi_g \equiv \varphi_{go}^{\overline{\omega}^I_{go}/1+\overline{\omega}^I_{go}}$

[64]The elasticity of a variety's price with respect to the tariff is thus, $\frac{\partial log(p^*_{gv})}{\partial log(\tau^I_g)} = \frac{-\omega^I_{gv}(1+\overline{\omega}^I_{go}\sigma^I_g)}{(1+\overline{\omega}^I_{go})(1+\omega^I_{gv}\sigma^I_g)}\frac{\tau^I_g}{1+\tau^I_g}$.

[65]The elasticity of a variety's exports with respect to the tariff is thus, $\frac{\partial log(x_{gv})}{\partial log(\tau^I_g)} = \frac{-(1+\overline{\omega}^I_{go}\sigma^I_g)}{(1+\overline{\omega}^I_{go})(1+\omega^I_{gv}\sigma^I_g)}\frac{\tau^I_g}{1+\tau^I_g}$.

prices as,

$$(1+\tau_g^I)^{1-\sigma_g^I} b_{gv} p_{gv}^{*1-\sigma_g^I} = (1+\tau_g)^{1-\sigma_g^I} b_{gv} \left(\varphi_{gv}(1+\tau_g)^{-\sigma_g^I} \mathcal{P}_g^{\sigma_g^I-1}\right)^{\frac{\omega_{gv}^I(1-\sigma_g^I)}{1+\omega_{gv}^I\sigma_g^I}}$$

$$\implies \qquad b_{gv} p_{gv}^{1-\sigma_g^I} = (1+\tau_g)^{\frac{1-\sigma_g^I}{1+\omega_{gv}^I\sigma_g^I}} b_{gv} \left(\varphi_{gv} \mathcal{P}_g^{\sigma_g^I-1}\right)^{\frac{\omega_{gv}^I(1-\sigma_g^I)}{1+\omega_{gv}^I\sigma_g^I}}.$$

Aggregating to match the form of the CES price index yields,

$$\mathcal{P}_g = \left(\sum_v (1+\tau_g)^{\frac{1-\sigma_g^I}{1+\omega_{gv}^I\sigma_g^I}} b_{gv} \left(\varphi_{gv} \mathcal{P}_g^{\sigma_g^I-1}\right)^{\frac{\omega_{gv}^I(1-\sigma_g^I)}{1+\omega_{gv}^I\sigma_g^I}}\right)^{\frac{1}{1-\sigma_g^I}}$$

Taking logs of both sides and isolating an arbitrary variety (denoted by o with export supply elasticity $\overline{\omega}_{go}^I$) yields,

$$log(\mathcal{P}_g) = \frac{1}{1-\sigma_g^I}\left[\log\left((1+\tau_g)^{\frac{1-\sigma_g^I}{1+\overline{\omega}_{go}^I\sigma_g^I}} b_{go} \left(\varphi_{go}\mathcal{P}_g^{\sigma_g^I-1}\right)^{\frac{\overline{\omega}_{go}^I(1-\sigma_g^I)}{1+\overline{\omega}_{go}^I\sigma_g^I}}\right) + \log\left(\frac{\sum_v (1+\tau_g)^{\frac{1-\sigma_g^I}{1+\omega_{gv}^I\sigma_g^I}} b_{gv} \left(\varphi_{gv}\mathcal{P}_g^{\sigma_g^I-1}\right)^{\frac{\omega_{gv}^I(1-\sigma_g^I)}{1+\omega_{gv}^I\sigma_g^I}}}{(1+\tau_g)^{\frac{1-\sigma_g^I}{1+\overline{\omega}_{go}^I\sigma_g^I}} b_{go} \left(\varphi_{go}\mathcal{P}_g^{\sigma_g^I-1}\right)^{\frac{\overline{\omega}_{go}^I(1-\sigma_g^I)}{1+\overline{\omega}_{go}^I\sigma_g^I}}}\right)\right]$$

The goal is to solve for the price index solely as a function of the tariff and market characteristics. Separating the last term above and applying the market clearing price condition for variety o produces,

$$\log(\mathcal{P}_g) = \log\left((1+\tau_g)^{\frac{1}{1+\overline{\omega}_{go}^I\sigma_g^I}} b_{go}^{\frac{1}{1-\sigma_g^I}} \left(\varphi_{go}\mathcal{P}_g^{\sigma_g^I-1}\right)^{\frac{\overline{\omega}_{go}^I}{1+\overline{\omega}_{go}^I\sigma_g^I}}\right) + \log\left(\frac{\mathcal{P}_g}{b_{go}^{\frac{1}{1-\sigma_g^I}}(1+\tau_g)p_{go}^*}\right)$$

With a little algebra we can eliminate the unobservable component of demand for variety o, b_{go}. Additionally, we will assume there exists a variety of import that charges exactly the CES average price in the importing country and that this variety is variety o. Consequently, $\log\left(\frac{\mathcal{P}_g}{(1+\tau_g)p_{go}^*}\right) = \log\left(\frac{\mathcal{P}_g}{p_{go}}\right) \equiv 0$ and,

$$\log(\mathcal{P}_g) = \frac{1}{1+\overline{\omega}_{go}^I\sigma_g^I}\log(1+\tau_g) + \frac{\overline{\omega}_{go}^I(\sigma_g^I-1)}{1+\overline{\omega}_{go}^I\sigma_g^I}\log(\mathcal{P}_g) + \frac{\overline{\omega}_{go}^I}{1+\overline{\omega}_{go}^I\sigma_g^I}log(\varphi_{go})$$

Solving for the log of the price index yields,

$$\log(\mathcal{P}_g) = \frac{1}{1+\overline{\omega}_{go}^I}\log(1+\tau_g^I) + \frac{\overline{\omega}_{go}^I}{1+\overline{\omega}_{go}^I}log(\varphi_{go})$$

Letting $\Phi_g \equiv \varphi_{go}^{\overline{\omega}_{go}^I/1+\overline{\omega}_{go}^I}$, we can write the price index solely as a function of the tariff, elasticities and variety specific unobservables,[66]

$$\mathcal{P}_g = (1+\tau_g^I)^{\frac{1}{1+\overline{\omega}_{go}^I}}\Phi_g. \tag{25}$$

E Alternate Specifications

For robustness, it is worth acknowledging that BLW put little stock in the direct relationship between their applied and optimal tariffs due to perceived measurement error in their estimates. Since our export supply elasticity estimates present with a similar long right tail, we might harbor the same concerns. To address potential measurement error, we follow BLW's tercile method which defines low, medium and high optimal

[66] For those following Broda et al. (2006), the result in Equation (25) is similar to an index of unobservable variety specific shocks as, $\Phi_g \equiv \varphi_{go}^{\frac{\overline{\omega}_{go}^I}{1+\overline{\omega}_{go}^I}} \simeq \left(\sum_v b_{gv}\varphi_{gv}^{\frac{\omega_{gv}^I(1-\sigma_g^I)}{1+\omega_{gv}^I\sigma_g^I}}\right)^{\frac{1+\sigma_g^I\overline{\omega}_{go}^I}{(1+\overline{\omega}_{go}^I)(1-\sigma_g^I)}}$, which is how Broda et al. (2006) represent the price index.

tariffs within an importer across its products.[67]

Table A1: Optimal Tariffs: The Impact of WTO Membership

	Years Since WTO Accession										
	-5^+	-4	-3	-2	-1	0	1	2	3	4	5^+
High BLW	1.002^{***}	0.518^{***}	0.426^{***}	0.476^{***}	0.414^{***}	0.365^{***}	0.308^{***}	0.258^{***}	0.034	0.056^{*}	0.151^{***}
	(0.037)	(0.043)	(0.038)	(0.035)	(0.034)	(0.033)	(0.032)	(0.032)	(0.032)	(0.031)	(0.015)
Mid BLW	1.521^{***}	0.812^{***}	0.620^{***}	0.596^{***}	0.476^{***}	0.402^{***}	0.340^{***}	0.333^{***}	0.094^{***}	0.124^{***}	0.211^{***}
	(0.037)	(0.040)	(0.034)	(0.031)	(0.030)	(0.029)	(0.028)	(0.029)	(0.030)	(0.029)	(0.015)
R^2	0.517	0.475	0.535	0.534	0.546	0.523	0.468	0.400	0.462	0.478	0.536
Obs.	539057	127964	136417	153963	167352	175251	180144	186838	142097	146323	561966
	-5^+	-4	-3	-2	-1	0	1	2	3	4	5^+
High $\tau_g^{I^*}$	2.275^{***}	1.115^{***}	1.058^{***}	1.041^{***}	0.936^{***}	0.958^{***}	0.968^{***}	1.108^{***}	1.095^{***}	1.117^{***}	1.030^{***}
	(0.039)	(0.041)	(0.036)	(0.033)	(0.032)	(0.030)	(0.029)	(0.030)	(0.031)	(0.029)	(0.015)
Mid $\tau_g^{I^*}$	0.700^{***}	0.877^{***}	0.895^{***}	0.907^{***}	0.801^{***}	0.902^{***}	0.792^{***}	0.937^{***}	0.869^{***}	0.903^{***}	1.115^{***}
	(0.037)	(0.045)	(0.038)	(0.034)	(0.033)	(0.031)	(0.029)	(0.030)	(0.029)	(0.028)	(0.015)
R^2	0.518	0.476	0.538	0.536	0.548	0.527	0.472	0.403	0.466	0.479	0.536
Obs.	510347	121597	129695	146679	159674	167399	172168	178584	136990	141109	541376

Notes: Each column regresses applied tariffs on the tercile of optimal tariffs in the subsample defined by years since WTO accession (superscript + indicates years or more). Mid BLW and High BLW are indicators for the second and third tercile of optimal tariffs under homogeneity. Mid $\tau_g^{I^*}$ and High $\tau_g^{I^*}$ are indicators for the second and third tercile of optimal tariffs under heterogeneity. All regressions include importer and industry fixed effects. Robust standard errors are in parentheses, where * p<0.10, ** p<0.05, *** p<0.01 indicate significance.

With terciles defined, Table A1 repeats Table 8 replacing the log of the optimal tariffs with tercile indicators. The results are even more pronounced than Table 8. In Table A1 the relationship of mid-high optimal tariffs and applied tariffs dissipates rapidly under homogeneity. The relationship even loses statistical significance when the importer has been a WTO member for three or more years. Conversely, there is a persistent strong positive relationship between applied and optimal tariffs with heterogeneity. Our estimates suggest that for goods in the top tercile of optimal tariffs, importers set tariffs around 1-2 percentage points higher than goods in the bottom tercile under heterogeneity.

[67] Notably, the raw correlation between the optimal tariffs with heterogeneity and homogeneity improves only slightly if we compare the newly defined terciles – The raw correlation within each importer is around 0.10 on average.

F Region Classification

Table A2: Countries and Regions

ISO	New ISO	Country
Top GDPs:		
AUS	AUS	Australia
BRA	BRA	Brazil
CAN	CAN	Canada
CHN	CHN	China
HKG	CHN	Hong Kong
DEU	DEU	Germany
FRA	FRA	France
GBR	GBR	UK
IND	IND	India
ITA	ITA	Italy
JPN	JPN	Japan
MEX	MEX	Mexico
RUS	RUS	Russia
USA	USA	USA
Africa:		
BDI	AFR	Burundi
BEN	AFR	Benin
BFA	AFR	Burkina Faso
BWA	AFR	Botswana
CAF	AFR	Central Afr
CIV	AFR	Cote d'Ivory
CMR	AFR	Cameroon
COG	AFR	Congo
COM	AFR	Comoros
CPV	AFR	Cape Verde
DZA	AFR	Algeria
EGY	AFR	Egypt
ETH	AFR	Ethiopia
GAB	AFR	Gabon
GHA	AFR	Ghana
GIN	AFR	Guinea
GMB	AFR	Gambia
KEN	AFR	Kenya
MAR	AFR	Morocco
MDG	AFR	Madagascar
MLI	AFR	Mali
MOZ	AFR	Mozambique
MRT	AFR	Mauritania
MUS	AFR	Mauritius
MWI	AFR	Malawi
MYT	AFR	Mayotte
NAM	AFR	Namibia
NER	AFR	Niger
NGA	AFR	Nigeria
REU	AFR	Reunion
RWA	AFR	Rwanda
SDN	AFR	Sudan
SEN	AFR	Senegal
STP	AFR	Sao Tome
SWZ	AFR	Swaziland
SYC	AFR	Seychelles
TGO	AFR	Togo
TUN	AFR	Tunisia
TZA	AFR	Tanzania
UGA	AFR	Uganda
ZAF	AFR	South Africa
ZMB	AFR	Zambia
ZWE	AFR	Zimbabwe
Asia:		
AFG	ASA	Afghanistan
ARE	ASA	Arab Emirates
ARM	ASA	Armenia
AZE	ASA	Azerbaijan
BGD	ASA	Bangladesh
BHR	ASA	Bahrain
BRN	ASA	Brunei
BTN	ASA	Bhutan
CYP	ASA	Cyprus
GEO	ASA	Georgia
Asia cont'd:		
IDN	ASA	Indonesia
IRN	ASA	Iran
ISR	ASA	Israel
JOR	ASA	Jordan
KAZ	ASA	Kazakhstan
KGZ	ASA	Kyrgyzstan
KHM	ASA	Cambodia
KOR	ASA	Rep of Korea
KWT	ASA	Kuwait
LBN	ASA	Lebanon
LKA	ASA	Sri Lanka
MDV	ASA	Maldives
MMR	ASA	Myanmar
MNG	ASA	Mongolia
MYS	ASA	Malaysia
NPL	ASA	Nepal
OMN	ASA	Oman
PAK	ASA	Pakistan
PHL	ASA	Philippine
PSE	ASA	Occ. Pales
QAT	ASA	Qatar
SAU	ASA	Saudi Arabia
SGP	ASA	Singapore
SYR	ASA	Syria
THA	ASA	Thailand
TUR	ASA	Turkey
TWN	ASA	Taiwan
VNM	ASA	Viet Nam
YEM	ASA	Yemen
Caribbean:		
ABW	CAR	Aruba
ATG	CAR	Antigua
BHS	CAR	Bahamas
CUB	CAR	Cuba
DMA	CAR	Dominica
DOM	CAR	Dominican Rep
GLP	CAR	Guadeloupe
GRD	CAR	Grenada
JAM	CAR	Jamaica
KNA	CAR	Saint Kitt
LCA	CAR	Saint Luci
MSR	CAR	Montserrat
MTQ	CAR	Martinique
TTO	CAR	Trinidad
VCT	CAR	Saint Vinc
Oceania:		
COK	OCE	Cook Isds
FJI	OCE	Fiji
KIR	OCE	Kiribati
NCL	OCE	New Caledo
NZL	OCE	New Zealand
PNG	OCE	Papua New
PYF	OCE	French Pol
TON	OCE	Tonga
TUV	OCE	Tuvalu
VUT	OCE	Vanuatu
WSM	OCE	Samoa
South America:		
ARG	SAM	Argentina
BLZ	SAM	Belize
BOL	SAM	Bolivia
BRB	SAM	Barbados
CHL	SAM	Chile
COL	SAM	Colombia
CRI	SAM	Costa Rica
ECU	SAM	Ecuador
GTM	SAM	Guatemala
GUF	SAM	French Gui
GUY	SAM	Guyana
South America cont'd:		
HND	SAM	Honduras
NIC	SAM	Nicaragua
PAN	SAM	Panama
PER	SAM	Peru
PRY	SAM	Paraguay
SLV	SAM	El Salvador
SUR	SAM	Suriname
URY	SAM	Uruguay
VEN	SAM	Venezuela
Northern & Western Europe:		
ANT	NWU	Neth. Anti
AUT	NWU	Austria
BEL	NWU	Belgium
BLX	NWU	Belg-Lux
CHE	NWU	Switzerland
DNK	NWU	Denmark
EST	NWU	Estonia
FIN	NWU	Finland
FRO	NWU	Faeroe Isd
GRL	NWU	Greenland
IRL	NWU	Ireland
ISL	NWU	Iceland
LTU	NWU	Lithuania
LUX	NWU	Luxembourg
LVA	NWU	Latvia
NLD	NWU	Netherland
NOR	NWU	Norway
SWE	NWU	Sweden
Southern & Eastern Europe:		
ALB	SEU	Albania
AND	SEU	Andorra
BGR	SEU	Bulgaria
BIH	SEU	Bosnia Herz
BLR	SEU	Belarus
CZE	SEU	Czech Rep.
ESP	SEU	Spain
GRC	SEU	Greece
HRV	SEU	Croatia
HUN	SEU	Hungary
MAC	SEU	Macedonia
MDA	SEU	Moldova
MKD	SEU	TFYR of Mace
MLT	SEU	Malta
MNE	SEU	Montenegro
POL	SEU	Poland
PRT	SEU	Portugal
ROM	SEU	Romania
SER	SEU	Senegal
SRB	SEU	Serbia
SVK	SEU	Slovakia
SVN	SEU	Slovenia
UKR	SEU	Ukraine