Optimal Tariffs: The Evidence*

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Abstract

The theoretical debate over whether countries can and should set tariffs in response to export elasticities goes back over a century to the writings of Edgeworth (1894) and Bickerdike (1907). Despite the optimal tariff argument's centrality in debates over commercial policy, there exists no evidence about whether countries actually use it in setting tariffs. We estimate disaggregate export elasticities and find evidence that countries that are not members of the World Trade Organization systematically set higher tariffs on goods that are supplied inelastically. The result is robust to the inclusion of political economy variables and a variety of model specifications. Moreover, we find that countries with higher aggregate market power have on higher average tariffs. In short, we find strong evidence in favor of the optimal tariff argument.

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1. Introduction

The idea that countries set tariffs in response to their market power in international markets is the single most controversial result in international trade policy. It is not hard to find examples of first class theorists arguing that it provides the underlying motive for the world trading system (Bagwell and Staiger [1999]) while others argue that it is little more than an intellectual curiosity with no practical value in all but the largest countries (Krugman and Obstfeld [1997]). Given that the theoretical debate over optimal tariffs goes back almost two centuries, one might well ask, "What evidence is there in favor or against the notion that tariffs vary inversely with export supply elasticities?" The answer is none.

In this paper we provide evidence that countries who are not members of the World Trade Organization systematically set higher import tariffs on goods that are supplied inelastically. The result is robust to the inclusion of political economy variables and a variety of model specifications. Moreover, we find that countries that have more aggregate market power have on average higher tariffs. In short, we find strong evidence that countries follow the optimal tariff argument in setting tariffs.

The theory that a country might gain from protection has a long history (c.f. Irwin [1996]).[1] The intuition for why countries might gain from tariffs through an improvement in their "terms-of-trade" stems from two key insights. The first, from Torrens (1833) and Mill (1844), is that while free trade raises national income relative to autarky, there are many possible prices at which countries would be willing to trade. The imposition of a tariff creates a welfare loss due to consumption and production distortions, but it can also produce a gain if foreign suppliers reduce

[1] Much of our discussion of the history of thought on optimal tariffs is drawn from Irwin's comprehensive book on the subject. All of our quotes from Edgeworth are drawn from this work.

their prices in order to maintain market access. If the losses due to the domestic distortion are less than the gains from the price or terms-of-trade effect, a country can gain from a tariff.

The key insight regarding when a country should impose a tariff was developed by Edgeworth (1894). He showed that as long as a foreign country's offer curve was not perfectly elastic, a country could gain from a tariff. If a country's tariff caused exporters not to change the quantity supplied much because they lower their price in order to maintain some of their market access, then there would be gains from imposing a tariff. Bickerdike (1907) extended Edgeworth's framework and developed, in a partial equilibrium setting, the formula equating the welfare maximizing (or optimal) tariff and the inverse of the export supply elasticity. His ability to derive a closed-form solution to the optimal tariff problem was praised by Edgeworth as having "accomplished a wonderful feat." Indeed, Bickerdike's equation serves as the basic theoretical equation we will examine in this paper. Although Bickerdike framed his derivation in a partial equilibrium setting, it can also be derived in a general equilibrium setting (e.g. Grossman and Helpman [1995]) under the assumption of quasilinear utility.

Despite its long and distinguished history, trade economists have long been uncomfortable with the optimal tariff argument (Irwin [1996]). Edgeworth (1908, p. 554), himself, expressed worry that although the theory seemed "to justify the imposition of small customs duties, say from 2 ½ to 5 percent on a great number of articles… it is to be feared that its abuse will be considerable." Over the years, economists have developed many other objections. Many economists argue that small countries cannot affect international prices and therefore this cannot be the reason we see tariffs in these countries. For example, Krugman and Obstfeld (1997) write in their undergraduate textbook, "Most small countries have very little ability to affect the world prices of either their imports or other exports, so that the terms-of-trade argument is of little practical importance" (p. 226). Other economists have argued that even if it is true in theory, it is too hard or complex to implement. For example, Feenstra (2004) in his graduate textbook argues "the formula is not very helpful because there is little that we know empirically about the elasticity of foreign export supply." Finally, economists have argued that countries may not impose optimal tariffs if they will trigger retaliation.[2]

Despite the skepticism regarding the practical importance of the optimal tariff argument, it continues to feature prominently in the leading theoretical trade policy models. Grossman and Helpman (1995) extend their endogenous trade policy model to the "large country case" – a case where the elasticity of export supply curves are not infinite. Although not stressed in the paper, there would be no motive for trade talks in their model in the absence of a terms-of-trade use of the tariff. This is a key point made by Bagwell and Staiger (1999) who provide an economic theory of the General Agreement on Trade and Tariffs (GATT). In this and in subsequent work, Bagwell and Staiger have strongly argued that the use of tariffs to explore the terms-of-trade effect can explain many of the key features of the current multilateral trading system. Their work has been quite influential despite the fact that there is no direct evidence that countries use, or indeed possess, market power in trade prior to entering into reciprocal liberalization in the GATT or WTO.

The measurement of this market power constitutes one of the important contributions of this paper. Since the optimal tariff argument hinges directly on the magnitudes of export supply elasticities they are a prominent feature of our analysis. We rely on the methodology of Feenstra (1994) and Broda and Weinstein (2004) to estimate these elasticities for each 4-digit Harmonized System (HS) category in 15 different non-WTO members during the period 1994-2003.

[2] Johnson (1953) shows that certain countries may actually gain from using optimal tariffs despite retaliation.

We find the inverse export supply elasticity for the typical 4-digit HS good to be between 1 and 3. We also show that several conjectures about the behavior of these elasticities across goods and countries are supported in the data. For example, we find that larger countries face less elastic export supply curves, which indicates that, on average, they have more market power than small countries. We also find that the higher a country's share in world imports in a particular good, the smaller the export supply elasticities it faces. This suggests some scope for small countries to have non-zero optimal tariffs in sectors in which they are big importers. Moreover, the export supply elasticities for the same good across importing countries are similar, and elasticities vary substantially across goods.

The estimation of these elasticities enables us to identify the key finding of our empirical work: the strong positive correlation between observed tariffs of non-WTO members and the inverse export supply elasticity. This relationship is present both when we compare median tariff rates across countries and when we compare actual tariff rates across Harmonized Tariff System (HS) 4-digit sectors within countries. In particular, if we classify goods in each country according to their inverse export supply elasticity, we find that the tariff is about 14% higher in those goods for which a country has medium or high market power relative to those in which it has the least market power. This figure more than doubles for the subset of countries in which we can also control for political economy determinants of tariffs. For instance, the average Chinese tariff for products with low inverse elasticities is 20.5 percent, while it is 28 percent for products where it is high: a 37% increase.

The relationship is robust to many different specifications, e.g. using continuous versions of the export supply elasticity measure, and across many different samples. In particular, it is robust to the inclusion of political economy variables. We construct a variable that is common across various types of political economy models: the inverse import penetration weighted by the import demand elasticity (Helpman [1997]). As is common in recent tests of the political economy models (e.g. Goldberg and Maggi [1999]) we find that the effect of import penetration variables are strong and significant, but nonetheless, the strong positive relationship between tariffs and the inverse export elasticity remains. In short, we conclude that the evidence is consistent with the tariff setting policy postulated by Edgeworth over 100 years ago.

The paper is organized as follows. We first provide the basic theory that we test. In section 3 we describe the estimation methodology we use for the elasticities. In section 4 we describe the data and assess the valid of the elasticity estimates. In section 5 we present the estimation results.

2. Theory

The basic theory underlying the optimal tariff argument is well established. Therefore in this section we provide the basic intuition for the result and show how it is robust to the inclusion of political economy considerations.

Suppose each individual has a utility defined over a numeraire good, c_0 , and a vector of non-numeraire goods **c**:

(1) $$U = c_0 + u(\mathbf{c}).$$

The elements in **c** can represent either a homogenous good, as is standard, or a consumption aggregate, as we also use later.

Each individual h with income I^h chooses expenditure on each good c_g to maximize U such that $c_0^h + \sum_g p_g c_g^h \leq I^h$, where p_g is the domestic price for c_g. Given the quasilinearity the demand for each non-numeraire good is independent of income. If we also assume that the utility is separable over goods, i.e. $\partial^2 u / \partial c_g \partial c_k = 0$ for all $g \neq k$, then demand for each good is also independent of prices of other goods and can be writen as $c_g = c_g(p_g)$.

An individual's indirect utility can be written as $v^h = I^h + s(\mathbf{p})$, where the last term represents a measure of consumer surplus.[3] Social welfare is then the sum of the individual indirect utilities over all individuals:

(2) $$W = \sum_h \left[I^h + s(\mathbf{p}) \right].$$

The standard assumption in some of the leading endogenous trade policy models, e.g. Grossman and Helpman (1994, 1995), is that the numeraire is freely traded and produced using only labor according to a constant returns production. The equilibrium wage is then determined by the marginal product in this sector, which we normalize to one. The non-numeraire goods are produced using a constant returns production with labor and one factor specific to the good, k_g. All H individuals own a unit of labor. A fraction of them also own up to one unit of specific capital. Therefore, the sources of income are wages, quasi-rents, π_g, and tariff revenues, r_g. Thus, we can rewrite social welfare as

(3) $$W = H + \sum_g \left[r_g \left(p_g \right) + Hs_g \left(p_g \right) + \pi_g \left(p_g \right) \right].$$

Note that since the wage is determined in the numeraire sector and capital is specific, the quasi-rent in the production of g can be written as a function of the producer price, which in the absence of production taxes equals the consumer price.

Most endogenous trade policy models focus on homogenous goods. In that case, the world price for each traded good $g \in G_m$ is determined by the market clearing conditions

(4) $$Hm_g \left(\left(1 + \tau_g \right) p_g^* \right) = m_g^* \left(p_g^* \right) \quad \forall g \in G_m$$

[3] More specifically, $s(\mathbf{p}) = \sum_g [u_g(c_g(p_g)) - p_g c_g(p_g)]$, with separable utility.

where Hm_g represents home's import demand written as a function of the domestic price, $p_g = (1+\tau_g) p_g^*$, and m_g^* is the rest of the world's export supply. From this we obtain prices as functions of the trade policy: $p_g(\tau_g)$, $p_g^*(\tau_g)$.

A government choosing the optimal tariff to maximize welfare in equation (3) will then set the tariff for each good *g* according to the following first order condition for each good:[4]

(5) $$\tau_g p_g^* \frac{dm_g}{d\tau_g} - m_g \frac{dp_g^*}{d\tau_g} = 0 \quad \forall g \in G_m .$$

If there is no domestic production in this good, the expression is the same with imports equal to consumption. The first term represents the domestic distortion caused by the tariff. The second term represents the terms-of-trade effect. If the country has no market power in trade, i.e. if the export supply elasticity is not infinite, then $dp_g^* / d\tau_g = 0$ and the optimal tariff is zero. Otherwise the optimal tariff is positive and can be shown to equal the inverse export supply elasticity,[5]

(6) $$\tau_g^{opt} = \omega_g \equiv \left[\left(dm_g^* / dp_g^* \right) \left(p_g^* / m_g^* \right) \right]^{-1} .$$

A common objection to the use of this expression to explain trade policy is that governments do not choose tariffs to maximize social welfare. However, equation (6) can also describe the equilibrium policy even when the government has other objectives, such as redistribution of income to particular specific factor owners. A key insight in the trade policy literature is that of targeting (e.g. Bhagwati and Ramaswami [1963]), which states that if a government has domestic objectives they can be met more efficiently using an instrument other

[4] By taking $dW/d\tau_g$ and using the envelope theorem, $ds(\mathbf{p}(\boldsymbol{\tau}))/d\tau_g = -c_g$, and $dp_g/d\tau_g = (dp_g^*/d\tau_g)(1+\tau_g) + p_g^*$.
[5] To obtain this we use the market clearing condition and the implicit function theorem to derive the expressions for $dp^*/d\tau$, $dp/d\tau$.

than tariffs, and that when these instruments target the distortion at the source, the optimal tariff is zero in a small economy. The counterpart to this insight for a large economy is that when the government's objective function includes some positive weight on social welfare, we obtain the optimal tariff expression in equation (6) provided that the government also uses other policy instruments (e.g. subsidies or transfers).[6]

Moreover, even if we rule out the use of non-tariff policy instruments, equation (6) still represents the optimal tariff in a number of special but interesting cases of political economy models. Grossman and Helpman (1995) extend their political contributions trade model to the large country case. The non-cooperative tariff that the government chooses in that model maximizes a weighted sum of social welfare and contributions, C_g, from the L organized lobbies representing specific factor owners, i.e. $aW+\sum_{g\in L}C_g$. In this case, the optimal tariff is

(7) $$\tau_g^{GH} = \omega_g + L_g$$

where L_g reflects the lobbying motive for tariffs and is given by

$$L_g = \frac{\pi'_g / Hm_g}{(\sigma_g - 1)} \frac{I_g - \alpha}{a + \alpha},$$

where σ_g -1 is the import demand elasticity. If a, the government's marginal rate of substitution between contributions and social welfare, is infinite then we obtain the optimal tariff. Even if it is finite, the optimal tariff in equation (6) is still the solution for all goods if all voters own specific factors, i.e. $\alpha = 1$ *and* all industries are organized into lobbies $I_g = 1$. That is also the solution for unorganized industries, $I_g = 0$,when factor ownership is highly concentrated, $\alpha = 0$. Otherwise the tariff for an organized group is increasing in π'_g / Hm_g, the inverse import penetration ratio,

[6] Most trade policy models that provide a political economy motive for a tariff must in fact rule out these other instruments; otherwise in those models the tariff's only role would be to affect the terms-of-trade. This is an example of the puzzle of the use of inefficient policies for redistribution. Rodrik (1995) points out it is particularly problematic for trade policy, Drazen and Limão (2004) provide one explanation for it.

because a given tariff generates larger benefits for a factor owner if it applies to more units sold. The tariff depends negatively on the import demand elasticity, ε_g, reflecting the basic Ramsey taxation intuition that, once the terms-of-trade effect is accounted for, the tariff's distortion is increasing in this elasticity. Helpman (1997) shows that the size and elasticity effect also arise in the context of other political economy models, so we will construct and use it as one of the controls in the estimation.

The key obstacle in estimating equation (6) is obtaining elasticity estimates for a broad set of countries and goods. In order to achieve this we must impose some structure on the data. We now briefly describe how the standard approach above can be extended in a way that is both compatible with our estimation of the elasticities *and* delivers the relationship in equation (6).

In the next section we describe the system of import demand and export supply equations that we use to estimate the elasticities. This system can be derived in a setting where any foreign variety (i.e. a good imported from a particular exporter) is valued according to a CES utility function, and supply is perfectly competitive. In the appendix we show that the optimal tariff in a model with CES utility over foreign varieties of a given good is identical to equation (6), i.e. the inverse export elasticity. This occurs when utility is separable across goods (but not varieties); the tariffs do not affect the relative demand of varieties within any given good; and hence the only distortion that addressed by the tariff is the terms-of-trade externality. There are three assumptions that imply the tariff in a good does not affect the relative demand of varieties within it, all of which driven by the constraints imposed by the data and estimation. First, consumption and export supply elasticities within any given good are constant. Second they are identical across varieties, i.e. exporters, of that good. Third, tariffs are equal across exporters of the same good.[7]

3. Estimating Export Supply and Import Demand Elasticities

As we have just seen, there is good theoretical justification for why we should expect to see a relationship between the tariff in a sector and the inverse export elasticity even in the presence of political economy considerations. The main reason why the relationship has not been estimated before is due to the difficulty of obtaining estimates of the elasticity of export supply. In this section, we explain how one can obtain estimates for the elasticities of import demand and export supply at the 4-digit harmonized standard level in each of the non-WTO countries in our sample.

One of the signature features of our estimation of these elasticities is that by double-differencing the data with respect to time and a base country, the data are completely independent of any good-time shock such as a change in tariffs for a particular good. Thus the level of tariffs on varieties or goods does not have any impact on our estimated elasticities.

We rely closely on the methodology derived in Feenstra (1994) as extended by Broda and Weinstein (2004) to estimate elasticities of substitution between varieties of imported goods. The latter estimates the following system of import demand and export supply equations:

(8) $$\Delta^{k_{ig}} \ln s_{igvt} = -\left(\sigma_{ig} - 1\right)\Delta^{k_{ig}} \ln p_{igvt} + \varepsilon_{igvt}^{k_{ig}}$$

(9) $$\Delta^{k_{ig}} \ln p_{igvt} = \frac{\omega_{ig}}{1+\omega_{ig}}\Delta^{k_{ig}} \ln s_{igvt} + \delta_{igvt}^{k_{ig}}$$

[7] If we took the optimal tariff argument to an extreme we may expect countries to optimally discriminate and choose different tariffs for different exporters of the same good. However in practice, we do not observe this. In fact even in the set of countries that we examine, which are not bound by the WTO to set identical tariffs on a given good from different countries, we find that tariffs are generally defined on the basis of a good and not origin (unless of course the country has a preferential trade agreement, but that is not the measure of protection we examine). One reason is that the administrative cost of optimal discrimination may be too high.

where $\Delta^{k_{ig}} x_{igvt} = \Delta x_{igvt} - \Delta x_{igk_{ig}t}$ (i.e., differencing across two different varieties of a given *i*-*g* pair), *i* denotes the importer country, *g* a 4-digit good, and *v* (for variety) a particular variety of good *g*. ε_{igvt} are taste or quality shocks to variety *v* of good *g* in country *i*, $\varepsilon^{k_{ig}}_{igvt} = \varepsilon_{igvt} - \varepsilon_{igk_{ig}t}$, δ_{igvt} are shocks to the supply of the same variety, and $\delta^{kig}_{igvt} = \delta_{igvt} - \delta_{igkt}$.

Equation (8) can be thought of as the optimal demand for intermediate varieties of good *g* derived from a CES utility function, and (9) is the supply of that variety expressed in terms of shares. In particular, the inverse elasticity of supply is given by ω_{ig} which is allowed to be different from zero but restricted to be the same for all varieties within an *i*-*g* pair. The import demand elasticity is σ_g-1. More importantly for the identification strategy is our assumption that $E\left(\varepsilon_{igvt}\delta_{igvt}\right) = 0$. That is, once good-time specific effects are controlled for, demand and supply errors at the variety level are assumed to be uncorrelated.

To derive the key moment conditions that will be used for identification, it is convenient to multiply (8) and (9) together to take advantage of the independence condition of errors:

$$\text{(10)} \qquad \left(\Delta^{k_{ig}} \ln p_{igvt}\right)^2 = \theta_{i1}\left(\Delta^{k_{ig}} \ln s_{igvt}\right)^2 + \theta_{i2}\left(\Delta^{k_{ig}} \ln p_{igvt}\Delta^{k_{ig}} \ln s_{igvt}\right) + u_{igvt}$$

where $\theta_{ig1} = \dfrac{\omega_{ig}}{\left(1+\omega_{ig}\right)\left(\sigma_{ig}-1\right)}$, $\theta_{ig2} = \dfrac{1-\omega_{ig}\left(\sigma_{ig}-2\right)}{\left(1+\omega_{ig}\right)\left(\sigma_{ig}-1\right)}$ and $u_{igvt} = \varepsilon^{k_{ig}}_{igvt}\ \delta^{k_{ig}}_{igvt}$. Note that the error term, u_{igvt}, is correlated with the regressands that depend on prices and expenditure shares. Therefore to consistently estimate $\boldsymbol{\beta}_{\mathbf{ig}} = \begin{pmatrix}\theta_{1ig}\\ \theta_{2ig}\end{pmatrix}$ we must exploit the panel nature of the dataset and use the assumption that demand and supply elasticities are constant over varieties of the same good. In particular, we can define a set of moment conditions for each good *g* and each importing country i, by using the independence of the unobserved demand and supply disturbances for each variety over time, that is,

$$G(\boldsymbol{\beta}_{\mathbf{ig}}) = E_t\left(u_{igvt}\left(\boldsymbol{\beta}_{\mathbf{ig}}\right)\right) = 0 \quad \forall v, g \text{ and } i. \tag{11}$$

For each good g and importer i, all the moment conditions that enter the GMM objective function can be stacked and combined to obtain Hansen's (1982) estimator:

$$\hat{\beta}_{ig} = \arg\min_{\beta_{ig} \in \mathrm{B}} \mathrm{G}^*\left(\beta_{\mathrm{ig}}\right)' W \mathrm{G}^*\left(\beta_{\mathrm{ig}}\right) \quad \forall g \text{ and } i. \tag{12}$$

where $\mathrm{G}^*\left(\boldsymbol{\beta}_{\mathbf{ig}}\right)$ is the sample analog of $G\left(\boldsymbol{\beta}_{\mathbf{ig}}\right)$ stacked over all varieties v of a good g, W is a positive definite weighting matrix to be defined below, and B is the set of economically feasible $\boldsymbol{\beta}_{\mathbf{ig}}$ which is common across importers and goods (i.e., $\sigma_{ig} > 1$ and $\omega_{ig} > 0 \quad \forall i, g$). We follow Broda and Weinstein (2004) in the way we implement this optimization. We first approximate (12) by estimating the "between" version of (10) to obtain estimates of θ_{1} and θ_{2} and then solving for $\boldsymbol{\beta}_{\mathbf{ig}}$ as in Feenstra (1994). If this produces imaginary estimates or estimates of the wrong sign we use a grid search of $\boldsymbol{\beta}$'s over the space defined by B. In particular, we evaluate the GMM objective function for values of $\omega_g \in [0.05, 131.5]$ at intervals that are 5 percent apart.[8] Standard errors for each parameter were obtained by bootstrapping the grid searched parameters.

The problem of measurement error in unit values motivates our weighting scheme. In particular, there is good reason to believe that unit values calculated based on large volumes are much better measured than those based on small volumes of imports. In the appendix of Broda

8 In the case of the import demand parameters, the grid search is performed over $\sigma_g \in [0.05, 131.5]$ at intervals that are 5 percent apart. To make sure that we were using a sufficiently tight grid, we cross-checked these grid-searched parameters with estimates obtained by non-linear least squares as well as those obtained through Feenstra's original methodology. Using our grid spacing, the difference between the parameters estimated using Feenstra's methodology and those obtained using the grid search differed only by a few percent for the 65 percent of sigmas for which we could apply Feenstra's approach.

and Weinstein (2004) they show that this requires us to add one additional term inversely related to the quantity of imports from the country and weight the data so that the variances are more sensitive to price movements based on large shipments than small ones. The use of the between estimate coupled with our need to estimate σ_g, ω_g, and a constant means that we need data from at least three exporting countries for each importer in each good and at least two time differences to identify β.

4. Data, Descriptive Statistics and Assessment of Elasticity Estimates

4.1. Data

In order to estimate equations (6) and (7) we need data on tariffs and domestic production as well as estimates of the elasticities. The first decision is what set of countries to include in our sample. Here we face both theoretical and empirical constraints. Since a, if not *the*, major function of the GATT/WTO is to allow countries to reciprocally lower their tariffs in order to internalize the terms-of trade effects, we should focus the test on non-GATT/WTO members.[9]

Our tariff data comes from the TRAINS database, which provides average tariff data at the 6-digit HS level.[10] Unfortunately, many non-WTO member states do not report tariff data for more than a small share of their import sectors making it impossible to compute country averages or do meaningful comparisons across goods within a country. We therefore decided to focus only on the fifteen non-WTO countries that report tariffs in at least one third of all sectors. The set of countries and the years we use are reported in Table 1.

The trade data is from two sources. Trade flows statistics are obtained from the United Nations Commodity Trade Statistics Database (COMTRADE). This database provides quantity

[9] Whether entering into the WTO really does lead countries to lower their tariffs in a way that no longer reflects the terms-of-trade motive, as predicted by Bagwell and Staiger (1999), is obviously an important and interesting question that will have to be addressed in another paper.
[10] TRAINS is an acronym for the United Nations Commission on Trade and Development's Trade Analysis and Information System.

and value data at 6-digit 1992 HS classification for bilateral flows between all exporting countries in the world. As we can see from table 1, the import data for most countries in our sample covers the period 1994-2003. COMTRADE does not report trade statistics for Taiwan, so for this country we use the bilateral trade flows reported in the UNCTAD's TRAINS database.[11]

4.2. Descriptive Statistics

The choice of what constitutes a good is somewhat arbitrary. Ideally we would like to define goods at the most disaggregate level possible, but the practical problem of doing so is that we would have so few varieties per good that our elasticity estimates would not be precise. We therefore decided to define a good as a 4-digit HS category and a variety as an import of a particular 6-digit good from a particular exporter. Table 2 shows that this implies we will be working with 1100 goods for the typical country, i.e. the typical country has 1100 4-digit categories with positive imports between 1994 and 2003. Similarly, if we define goods at the 4-digit sub-heading level and varieties of a good as pairs of 6-digit exporting country flows, we find that the typical good in the sample is imported from 17 different countries. For instance, there were 40 different varieties of live fish (4-digit HS 0301) imported by China in 2001, among them were "trout" (HS 030191) from Australia and "eels" (HS 030192) from Thailand. There are between 15,000 and 66,000 varieties of goods per year for each of these non-WTO members. The high degree of specialization of exports suggests that one should be cautious about assuming that the share of a country in world GDP is a sufficient proxy for the ability of a country to gain from a tariff. If China places a tariff on live fish, it is not clear that Thai eel producers can easily find another country to sell their eels.

[11] The two main differences between the Trains and Comtrade are: a) Trains contains only bilateral trade flows for countries which have tariff data. So, by definition, Trains is a subset of Comtrade; b) Trains has a cutoff "value" point for including a bilateral trade flow that is higher than Comtrade. In the case of Taiwan, there are still over 30,000 6-digit-exporting-country pairs and 900 4-digit sub-headings.

Table 2 also shows the means and medians of our tariff data. There are several important features to note. First, while there is a lot of variation across countries and industries, the average and median tariffs stand at 13 and 10 percent respectively. Moreover, 99 percent of all tariffs are below 82 percent and 95 percent of tariffs are below 42 percent. To get some sense for what share of these are likely to be prohibitive, one can compare these numbers to the estimates of reservation prices in Broda and Weinstein (2004). They estimate a linear version of their model and find that the median reservation price is around twice the observed import price. If this is approximately correct for these countries, then most tariffs we observe are unlikely to be prohibitive. There is also a fair amount of cross country variation in median and average tariff rates, ranging from around 31 and 38 percent in China to 1 and 7 percent in Latvia.

If one takes size, as measured by GDP, as a good proxy for market power then the data on tariff levels suggests that the skepticism regarding the optimal tariff argument is not entirely unwarranted. First, as we can see in Table 2, although China is both the largest country in our sample and has the highest tariff, Taiwan, the second largest country has a below average tariff. The correlation between median tariff and the log of GDP is 0.48 and that between average tariffs and GDP is 0.53 However if we drop China, those correlations fall to 0.05 and 0.10, respectively.

Data on the within-country variation also suggests that the tariff setting policies are likely to be more complex than a simple application of the optimal tariff calculus. Figure 1 portrays the within-country frequency distribution of tariffs at the 4-digit level. The results are quite striking. Bolivia, Latvia, Lithuania, Oman, and Saudi Arabia have a large number of tariffs with identical or near identical values. Bolivia is most extreme in this regard with 95 percent of its tariffs in the range of 9.4 to 10 percent. Similarly, a large share of Ecuadorian tariffs takes on one of four values. While some countries have a smooth distribution of tariffs, some countries like Bolivia have a large number of tariffs that take only a few discrete values. This suggests that even though tariffs levels are a continuous variable taking on many values in most countries, there are other countries, typically ones that reformed their policies and perhaps followed the common advice of economists to minimize tariff dispersion, where these tariffs take on only a few different values. Moreover we observe truncation and some bunching at the lower end of distribution with many tariffs set at zero

The data seems to militate against a simple relationship in which policymakers equate the tariff level with a continuous variable such as export elasticities or degrees of political power. One can imagine many reasons for this. Perhaps policy makers are uncertain of inverse elasticities or political connectedness and therefore divide their tariff schedule in various categories rather continuous levels; maybe policymakers employ other means of protection at their disposal when they want to achieve high levels of protection; maybe countries are averse to setting tariffs too high out of fear of retaliation; or maybe once tariffs hit prohibitive levels, there is no reason to raise them further.

Regardless of the reason, the preceding paragraph suggests that it may be too much to ask the data to reproduce the precise functional form of Bickerdike's (1907) optimal tariff formula, i.e. the tariff in a good exactly equals the inverse of the export supply elasticity. We can, however, contemplate weaker versions of the optimal tariff formula which maintain the essential insight of Edgeworth (1894). Namely, we should expect to see countries apply higher tariffs on goods that are less elastically supplied. If we observe a positive relationship between the two variables, we can conclude that the basic intuition that countries apply higher tariffs on inelastically supplied goods is correct. An obvious way of testing this weaker version of the theory is to ask whether there is a positive relationship between inverse export elasticities and tariff levels after we account for the truncation. This is the approach that we will adopt in the following sections.

4.3. Assessment of Elasticity Estimates

Our estimation strategy requires two phases. First we obtain estimates of import demand and supply elasticities, and second we use these to try to explain observed tariff levels. We use equation (12) to obtain our estimates of the elasticities of export supply of every imported good into each our 15 countries. Since we are conducting this analysis at the 4-digit level, we generated a total of 12,376 elasticities of supply estimates. This is far too many parameters to present individually. Therefore in Table 3 we report summary statistics of these elasticities. There clearly is a lot of variance and outliers in our estimated parameters, suggesting that we will need to be careful about measurement error in subsequent analysis. However, the medians, which give less weight to outliers than the averages, seem quite sensible. The median inverse elasticity is 1.6, implying a median elasticity of supply of 0.6, indicating that 1 percent increase in prices elicits a 0.6 percent increase in the volume of exports for the typical good.

We can explore the "reasonableness" of our estimated elasticities in three ways. First, we can try to assess whether they fit our priors about what they should be. Second, we can check whether elasticities for the same good estimated using data from two different countries are correlated. Third, since the trade literature has made much of the fact that elasticities of supply should be correlated with country size, we can ask whether this intuition is correct.

It is hard to have strong priors about what elasticities of export supply should be in particular industries without knowing much about world production structure. Moreover, if one combed through the 12,000 estimates one could easily find numerous examples of elasticities that either seemed implausibly big or small. However, it seems reasonable to conjecture that commodities are likely to be supplied more elastically than differentiated goods since on average it is unlikely that a country can have a larger impact on the world price of a good traded on an organized exchange. Rauch (1999) divided goods into three categories – commodities, reference priced goods, and differentiated goods – based on whether they were traded on organized exchanges, were listed as having a reference price, or could not be priced by either of these means.[12] Table 4A uses this classification and confirms the prediction by testing the differences of the mean inverse elasticities across each group of goods as classified by Rauch. The most striking feature of the table is that the median and mean *inverse* elasticities are much higher for differentiated products than for commodity or reference priced goods. In all but one case, we can strongly reject the hypothesis that differentiated products have the same average and median elasticity as reference priced goods and differentiated goods, and we can always reject the hypothesis that differentiated have the same elasticity as the combined set of reference priced and commodity goods (not reported).

Table 4B also reveals a similar pattern among the 15 goods that constitute the largest share of imports in the sample of countries studied. In particular, the three goods supplied most elastically (i.e. with the lowest median inverse elasticity) are soybeans, barley and oil. All of these goods constitute commodities for which it would be hard for a small importer to affect the price. By contrast, the three goods supplied most inelastically are integrated circuits, aircraft, and nuclear reactors. These goods seem more likely to be ones for which a country might have some

[13] The motive for a log regression is that the estimation procedure for the elasticities cannot yield non-positive estimates. Thus the distribution of parameter estimates is quite skewed with positive deviations from the median vastly exceeding negative ones in magnitude. The skewness is immediately apparent if one inspects the 10th, 50th, and 90th percentiles in Table 3. However, the density function of the log of the inverse export elasticity estimates has a pattern quite similar to a normal density plot.

negotiating power. Thus when we look at the biggest import categories our methodology seems to generate a reasonable ordering.

A second criterion for evaluating these estimates is to examine the similarities in estimates obtained from different datasets. While it is possible for elasticities of export supply for a given good to vary across importers, it would be disturbing if we could not identify some goods that were more or less elastically supplied. The motive is simple, the export supply curve faced by all importers of a given variety, i.e. from a given exporter, share one common term, the value of the exporters production minus its domestic consumption. In order to test whether there is some pattern in the supply elasticities we obtain, we tested whether the supply elasticity we estimated in one country is related to the supply elasticity estimated using import data from other countries. To test this we regress the log of the estimated inverse elasticity in a sector for a country against the log of the median inverse elasticity in the same sector computed using the data of the remaining 14 countries. We report these result in Table 3. The *t*-statistics and point estimates indicate that there is a very strong positive statistical relationship between the estimates of the export elasticity in a sector obtained using any one importer's data and the median export elasticity obtained using the data from the other countries. Since the datasets are completely different, these results suggest that the elasticities we estimate are not random; they contain information about systematic variation across goods.[13]

As a third check for the "reasonableness" of the elasticities, we examine whether they reflect the common intuition that market power is related to country size. Given that the largest country in our sample, China, represents only 3 percent of world GDP, it is entirely possible that the relationship between GDP and country size is weak in our data. Nevertheless, the intuition that country size should positively vary with the inverse elasticity is so ingrained in our intuition that it seems reasonable to look for it in our data. Again we have to face one estimation issue. Since some of our countries report tariffs in only one third of their sectors computing simple means and medians across different sets of sectors may be misleading. We therefore include HS 4-digit industry dummies in the regression so our results should be interpreted as comparing market power for different countries within each import sector.

Table 5 reports the results from the regression of log inverse export elasticities on log GDP. A positive coefficient in these regressions means that market power rises as GDP rises. The results indicate a very strong positive relationship between the log of an importer's GDP and the log of the inverse elasticity even after controlling for the clustering of the standard errors. The relationship is also positive and significant if we use the log of an importer's market share in each good instead of its GDP. Moreover, it remains strong even if we drop China or if we focus on the set of five countries for which we have both elasticity and political economy data. Hence our estimated elasticities also pass our third "reasonableness" check – larger countries have more market power.

In sum, the analysis above suggests that our elasticity estimates are "reasonable" by a number of criteria. First, when we look at the largest import sectors, we find that goods that we think of as commodities tend to be supplied elastically whereas differentiated goods are supplied more inelastically. Second, there is a high correlation between elasticities estimated in different datasets. And third, larger importers tend to have more market power than smaller importers. A remaining concern is the wide dispersion in these estimates, which is something we will need to correct for in the econometrics.

5. Empirical Results

5.1. Preview

We can now answer whether there is some relationship between the tariffs and export supply elasticities. Before turning to regression evidence, we will examine a data plot: the median tariff in each country against the median inverse export elasticity. There are many reasons to be skeptical that we can obtain a relationship in the cross section. We only have fifteen countries to work with so one may worry that outliers can dominate the results. In addition, the countries in our sample have very different political systems, economic conditions, and a very disparate mix of other protectionist tools – all of which are reasons to abandon hope that a relationship will be visible.

However, since the cross-sectional story of market power and tariffs has such prominence, we think it worthwhile to see if we can detect a relationship. Figure 2 presents median average tariff in a country against the median inverse elasticity. The results are astounding: there is an unmistakable positive relationship! The pattern seems to be driven by no one country or even set of countries on a particular continent or with a particular income level. The positive relationship between median tariffs and median elasticities is also statistically significant.[14]

Of course, there are many reasons to be wary of this relationship. First, in the cross-section we only have fifteen observations. Second, one should be inherently worried about a cross-country result in which one focuses on one variable to explain the difference in policy between, say, Oman and China. Fortunately, we have a vast quantity of country-good data underlying this plot that can be exploited to examine the relationship more carefully.

[14] If we regress the median tariff on the median inverse elasticity we obtain a positive and significant slope (slope = 19.3; standard error = 7.8; R^2 = 0.32).

Before plowing forward into the econometrics, it is worth reconsidering one important element of the data. At the upper extreme, our independent variable, the inverse export supply elasticity, takes on very large values. These very large inverse elasticities may reflect measurement error: an issue we will return to later. However, if the estimated levels are correct, these high inverse elasticities are clearly not compatible with a theory predicting a one-to-one relationship between inverse elasticities and tariffs. Of course, as we highlighted above, there are many good reasons, to suspect that the relationship between tariffs and inverse elasticities might be positive over some region and then level off. Therefore we report not only linear regressions analogous to the functional form derived by Bickerdike (1907) but also other specifications, which are more in the spirit of Edgeworth, that better capture the tariff setting behavior as elasticities move from high to low values.

In Table 6, we report the results of regressing average tariffs on the inverse export elasticity controlling for HS-4 digit industry fixed effects. These estimates can be thought of as the regression analog of Figure 2, where we are using the variation in inverse elasticities within industries but across countries to identify the relationship between inverse elasticities and tariffs. In columns 1, 2, 4, and 5 of Table 6, we can see that in both OLS and Tobit specifications there is a strong statistical relationship between inverse elasticities and tariff levels. In the linear specification, the coefficient is tiny (for reasons we will discuss shortly), but in the log specification the coefficient has a reasonable magnitude, 0.44. [15]

Obviously measurement error in the elasticity is a potential concern since it might be biasing our coefficients downwards. One solution is to find an instrument that is correlated with the inverse export elasticities but not with any country specific error. A reasonable instrument is

[15] In the latter specification a two standard deviation increase in the level of the inverse elasticity causes the tariff to increase by 1.3 percentage points. This effect holds at the sample mean, 85, and it increases to 3.1 pp if we evaluate the increase starting with a product that has the median inverse elasticity, which is 1.6.

the median inverse elasticity estimate taken over the other countries. In columns 3 and 6 we report instrumental variables estimates of the coefficient on the inverse elasticity. In both cases the coefficient rises, but in the linear case the standard error rises by more reflecting the fact that in levels the elasticities within each country vary by so much that the quality of our instrument is poor. However, the coefficient is positive and significant in the log specification. We also note that its magnitude, 0.47 is almost identical to the OLS estimate, 0.44 and therefore the measurement error does not seem important in generating any substantial attenuation bias. These regressions reveal that the picture we see in Figure 2 does reflect a strong positive association between the average tariff and the log of the inverse elasticity.

The results we have presented thus far are suggestive of a relationship but are far from convincing. In particular, we have already seen that China, Algeria, and Paraguay have high tariffs and high inverse elasticities. It is possible that our regressions are being driven by a handful of countries. Moreover, expressing the optimal tariff in terms of a country's size and market power is natural in a two-good model, but not very useful from an empirical perspective because of the many cross-country differences that may affect average tariff levels. Furthermore, as we have seen, the theory also provides important predictions for tariff variation within a country. Since there is generally much more variation in tariffs and elasticities within countries and fewer potential omitted variables we believe this is the more promising route. This is our focus in the next section.

5.2. Testing Optimal Tariff Theory: The Classical Approach

Our approach to testing the optimal tariff theory is two-pronged. In this section we focus on the classical approach, i.e. on testing a simple model where the inverse export supply elasticity is the key determinant. There are potentially several other factors highlighted by several political economy models that influence tariff setting behavior. Thus, in the next section we estimate a political economy augmented model. The main motive for this approach is a data constraint: we have tariff and elasticity data for 15 non-WTO countries but only 5 of these have the required data for the political economy augmented test.

Although the estimates in this section may not control for all relevant determinants they may still be quite valuable in testing the optimal tariff theory. First, as we described in the theory section, there are several special but important cases under which the tariff may be explained by focusing on the terms-of-trade effect alone. Second, in all subsequent regressions we will include country-level fixed effects, so that all of the variation we explore in HS 4-digit tariff rates within countries. Finally, given the way we estimated the elasticities they are unlikely to be correlated with a variety of omitted variables that vary across goods within a country.

We have two strategies to deal with the skewness and measurement error in our inverse export elasticity variable. As before, we can run regressions using the log of the variable or we can transform the variable into indicator variables that correspond to the lower, middle, or upper third of values. We therefore will report both estimates over the full sample and estimates that allow for the implied tariff to level off after some maximum value.

Table 7 reports our first set of results with country fixed effects. When we run the regression in a linear specification for the full sample, in column 4, we obtain a positive and significant coefficient on the inverse elasticity as predicted by theory, but the coefficient is tiny. The reason for this is that some of our estimates of the inverse elasticity are very large and imply implausibly large tariffs in a linear specification with a coefficient of any larger magnitude. In columns 3, 2 and 1 we use the observations with inverse export supply in the lowest 75^{th}, 50^{th} and 25^{th} percentile respectively. The coefficient on the inverse elasticity remains significant and rises by a factor of 20,000 when we focus only on the goods with the lowest inverse export supply elasticities! This suggests that while there is a strong positive relationship between these two variables, there is a tapering off of the magnitude of the association as the optimal tariff implied by the elasticity crosses some level.

One way to address this functional form issue is by using the log of average inverse elasticity. We do so and find that the coefficient on this variable is positive and significant in both the OLS and Tobit specifications, in columns 8 and 9 of Table 7 respectively. Finally, in columns 6 and 7 we address the measurement error and, to some extent, the functional form issue ,by sorting each country's data by the inverse elasticity and creating dummies corresponding to whether the inverse elasticity in an industry is in the lowest third, middle third, or highest third of the data. Tariffs are significantly lower, 1.2 percentage points, when goods are supplied elastically (i.e. have low inverse elasticities) than when goods have medium or high inverse elasticities. To better understand the relative importance of the terms-of-trade motive we can compare this increase to the average tariff in the country. This calculation reveals that for the representative country the terms-of-trade motive increases the tariff by 14%.

In sum, just as Edgeworth postulated over a century ago, all of our specifications indicate that elastically supplied imports have significantly lower tariffs than those supplied inelastically. *This is the first time anyone has ever documented a positive relationship between tariffs and export supply elasticities*.

5.3. Testing Optimal Tariff Theory: The Political Economy Augmented Model

The preceding analysis established that there is an unmistakable positive relationship between estimated inverse export supply elasticities and tariff levels for countries outside of the WTO. There are many good reasons to believe, however, that commercial policy is also strongly influenced by domestic political interests that may be completely independent of terms-of-trade considerations. One issue that we face is whether there may be some correlation between our estimates of the inverse elasticities and political economy variables. It is hard to see how there might be any systematic correlation between our estimates of export supply elasticities and political economy variables because all importer-industry-time variation has been purged from the elasticity data before estimation. However, the prior results may reflect some type of omitted variables bias in the estimates.

We admit that the specifics of the political economy that are relevant for the tariff structure is quite likely to differ across these countries. So our approach is to ask if our results are robust to the inclusion of a political economy variable that is central in an important model, Grossman and Helpman's, but that also plays a role in alternative political economy models. If we assume that all sectors are politically organized, the Grossman-Helpman model of tariff setting can be used to provide a particularly parsimonious characterization of the effects of both market power and domestic lobbying. In this model, tariffs will be given by equation (7), the sum of the inverse elasticity and the political economy variable, which we will refer to as the "inverse import penetration ratio." Recall that this variable equals the domestic production divided by the level of imports and the import demand elasticity. In order to construct the inverse import penetration ratio, we need data on domestic production. We can obtain this data for 5 of our fifteen countries – Bolivia, China, Ecuador, Latvia, and Taiwan. The most disaggregate level at which this is available for all these countries is at the ISIC 3-digit data from UNIDO's industrial database. Thus we construct the import penetration ratio at this level. However, we divide it by the import demand elasticity that we estimate at the HS-4 digit level. Thus the political economy variable still varies at the 4-digit.

We present a cross-tabulation of our 4-digit tariff data for these countries using the inverse export elasticity and the inverse import penetration variables in Table 8. Each element of Table 8 consists of the average percentage deviation of a tariff from the country mean for a given combination of inverse export elasticities and inverse import penetration ratios. For example, the element of the upper left corner of the table indicates that average tariffs in 4-digit sectors with inverse export elasticities in the lowest 33 percent of the distribution of inverse elasticities *and* inverse import penetration ratios in the lowest 33 percent of the distribution of inverse import penetration typically had tariffs 34 percent below the country average. As we move down the columns we see that the effect on the tariff differential in a sector of increasing the inverse export supply elasticity while holding the inverse import penetration variable fixed. As we move right along a row, we see the effect on the tariff differential in a sector of increasing the inverse import penetration variable.

There are a number of important features of Table 8. First, there is a very strong rise in tariffs relative to country averages as the inverse import penetration rises. This is clearly predicted by the Grossman-Helpman model and more generally it is consistent with the importance of domestic political economy effects in tariff-setting. Shifting from a sector with a low inverse import penetration ratio to a high one is associated with a 40-60 percent increase in tariff rates relative to the country average. Second, tariffs also rise as the inverse export elasticity rises as long as the inverse import penetration is not high. This suggests that at some point domestic political economy factors may swamp the optimal tariff argument of Edgeworth, but as long as these forces are not too strong, there is a strong positive association between inverse export elasticities.

In the first column of Table 9 we present the regression analog of Table 8. Here we regress tariffs on country dummies and dummies corresponding to whether the inverse export elasticity and inverse import penetration variables are in the lowest, middle, or highest third of their ranges. The excluded categories are low import penetration and inverse export elasticities, which are captured by each of the country intercepts. The coefficients on the medium and high dummies are then interpreted as the additional effect on tariff values in these countries for goods in such categories. Columns 2, 3 and 4 make corrections for various econometric issues: we run a tobit to correct for biases due to truncation of the dependent variable; we run a median regression to examine the impact of our variables of interest are on the median tariff rate, and we instrument the inverse import penetration portion of the political economy variable with the mean value in the other 4 countries to correct for the endogeneity between tariffs and inverse import penetration.[16]

No matter how we run our regressions we cannot eliminate the result that importers impose higher tariffs in sectors where goods are supplied less elastically (i.e. have a higher inverse export elasticity). The monotonicity of this relationship, comparing the medium and high effect, is present in the GMM estimates. All specifications confirm that importers impose lower tariffs in sectors with lower inverse export elasticities. The political economy variables have the predicted sign, and their inclusion does not eliminate the association between high inverse export elasticities and tariffs we found in the last section. Moreover, the magnitudes of the impact seem quite large relative to average tariffs in countries.

[16] A suitable instrument must be correlated with inverse import penetration but not with tariffs in the country. Given that the tariffs of our non-WTO sample of countries are not set jointly the average production to import ratio over any four countries is unlikely to be determined by the tariffs of the fifth. On the other hand, inverse import penetration variables in other countries are likely to be correlated with those in a particular country if there is some commonality in the tradability of certain ISIC 3 industries.

The last two columns of Table 9 report results using continuous variables instead of dummies. In Column 6 of Table 9 we report GMM estimates where we again instrument the political economy variable using the average for other countries The results indicate that controlling for political economy variables and instrumenting strengthen the coefficient on the inverse export elasticity that we reported earlier. Clearly, adding a variable to account for domestic political interests does not alter the relationship between inverse export elasticities and tariffs. A two standard deviation increase in the inverse elasticity leads to an increase in tariffs that ranges from 1 percentage point, if we start at the mean inverse elasticity, to 3 percentage points, at the median.

Up until this point we have been assuming that the relationship between inverse export elasticities and tariffs is common across countries. The reason for this is that by pooling our dataset we can obtain our estimates based on thousands of observations of tariffs. This increases the precision of our estimates. However, a reasonable objection to this approach is that there may exist radically different tariff setting processes across our sample of countries and thus the relationship between tariffs and our explanatory variables may vary substantially across countries.

In order to assess how important the optimal tariff argument is for individual countries we reran our regressions at the country level. We report these results in Table 10. Not surprisingly, moving from thousands to hundreds of observations per regression results in higher standard errors. However, in the IV regressions we can reject the hypothesis that sectors with high inverse elasticities are not higher than those with low inverse levels at the 5 percent level for every country except Bolivia. Similarly, there is an even stronger statistical difference between sectors with high and low inverse import penetration ratios.[17] The quantitative importance of the effect is clear if we compare the increase in tariff caused by high inverse elasticities. It ranges from 1% for Bolivia to 86% for Latvia. China and Taiwan have identical effects, 38% and Ecuador 15%. The median is 37%.

By far the weakest results when we use the dummies are for Bolivia. As we saw in Figure 1, Bolivian tariffs hardly vary at all – about 90% of the tariff lines in our sample for Bolivia have tariffs of 10 percent, 5 observations have a tariff of 5 percent and the remainder are in between. Clearly, this tariff structure does not fit the stylized optimal tariff models we have been discussing so far. However, we can ask if there is anything we can say about the sectors in which Bolivia deviates from the common tariff of 10 percent. We can answer this question by running a censored normal regression in which we have two censoring points: a lower bound of 5 percent and an upper bound of 10 percent. The estimated coefficients on both the export and import variables then come in strongly with the right sign. Their magnitudes are strikingly close to those we estimate for the pooled sample in table 9. In other words, Bolivia is the exception that proves the rule – even when a country has a tariff structure that hardly varies; the sectors where the tariffs tend to be low correspond to sectors with low inverse export elasticities and low political power.

6. Conclusion

The idea that a country could improve its terms-of-trade through the imposition of tariffs has been in the economics literature for close to two centuries. Economists have known for over one century that the optimal tariff in sectors where goods are not supplied elastically is positive. However, thus far, perhaps due to data and computational issues, no one has tested whether

[17] In the OLS regressions, we observe the same sign pattern although the attenuation of the coefficient estimates arising from the measurement error means that we can't statistically distinguish the relationship. However, given the endogeneity of the import penetration variable we believe that the IV estimates are the correct ones.

countries do so. This paper is the first econometric exercise documenting that importers who are not members of the GATT/WTO do impose higher tariffs on goods with lower export supply elasticities. This result is present when looking at tariffs across countries, across sectors within countries, and even after controlling for political economy considerations.

We also find evidence that political economy forces also matter for tariff setting behavior. This suggests that both political economy and international market power are important forces in the determination of protection.

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Figure 1

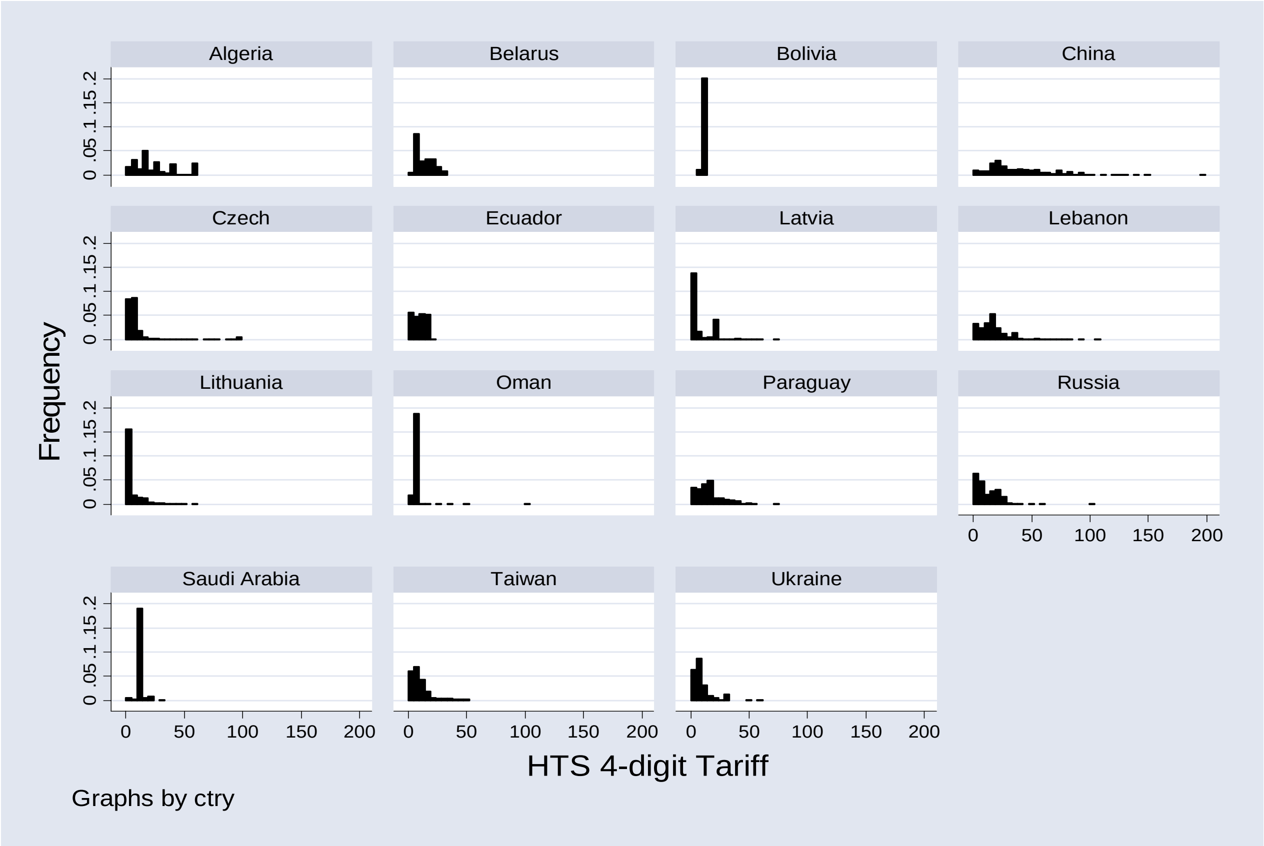
Algeria
Belarus
Bolivia
China
Czech
Ecuador
Latvia
Lebanon
Lithuania
Oman
Paraguay
Russia
Saudi Arabia
Taiwan
Ukraine
Frequency
0 .05 .1 .15 .2
0 50 100 150 200
HTS 4-digit Tariff
Graphs by ctry

Figure 2

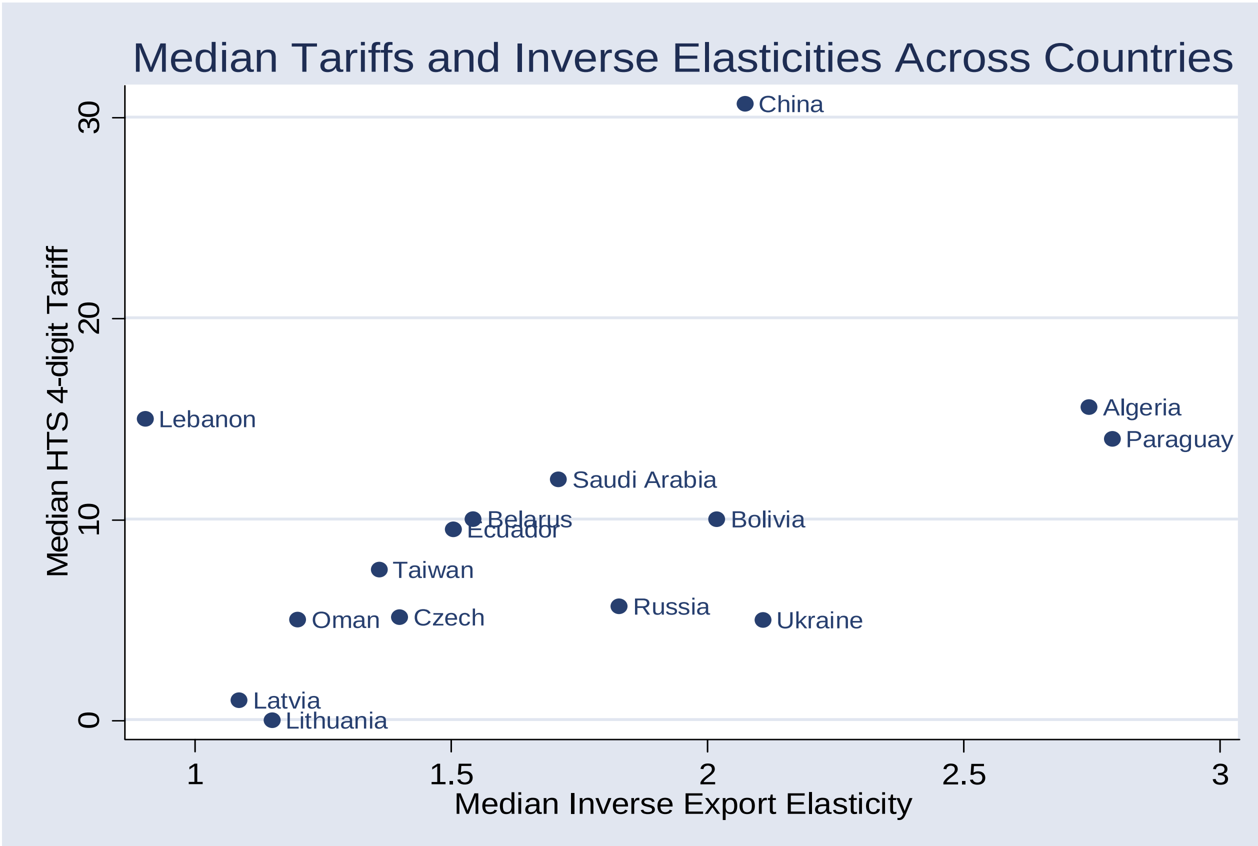
Median Tariffs and Inverse Elasticities Across Countries
Median HTS 4-digit Tariff
Median Inverse Export Elasticity
0
10
20
30
1
1.5
2
2.5
3
China
Lebanon
Algeria
Paraguay
Saudi Arabia
Belarus
Ecuador
Bolivia
Taiwan
Russia
Oman
Czech
Ukraine
Latvia
Lithuania

Table 1: Data Sources and Years used

	WTO Accession Date	GATT Accession Date	Production Data		Tariff Data (1)	Trade Data (2)
			Source	Years		
Algeria					93	94-03
Belarus					97	98-03
Bolivia	1-Jan-1995	8-Sep-1990	UNIDO	93	93	94-03
China			UNIDO	93	93	94-03
Taiwan	1-Jan-2002		UNIDO	96	96	94-03
Czech	1-Jan-1995	15-Apr-1993			92	94-03
Ecuador	21-Jan-1996		UNIDO	93	93	94-03
Latvia	10-Feb-1999		UNIDO	96	97	94-03
Lebanon					00	97-02
Lithuania	31-May-2001				97	95-03
Oman					92	94-03
Paraguay	1-Jan-1995	6-Jan-1994			91	94-03
Russian					94	96-03
Saudi Arabia					91	94-03
Ukraine					97	96-02

(1) All tariff data is from TRAINS. Countries are included if we have tariff data for at least one year before accession (GATT/WTO).
(2) Except for Taiwan, all trade data is from COMTRADE. For Taiwan data if from TRAINS.
(3) Although the tariff data for Bolivia is post-GATT accession it was actually set before GATT accession and not changed between 1990-93.

Table 2: Trade and Tariff Data Description

	Number of Varieties (1)	Number of 4-digit HS	Median # of Var per HS4	Tariff Rate per 4-digit HS code			
				Mean	Median	10th Percentile	90th Percentile
Algeria	26466	1100	13	23.8	15.6	6.2	60.0
Belarus	24440	1172	12	12.4	10.0	5.0	25.0
Bolivia	18592	1064	9	9.9	10.0	10.0	10.0
China	63764	1217	33	37.9	30.7	12.0	75.0
Taiwan	38397	1215	19	9.6	7.5	0.0	20.0
Czech	61781	1219	30	9.5	5.1	0.0	14.6
Ecuador	22979	1101	11	9.4	9.5	2.0	17.0
Latvia	33790	1128	17	7.0	1.0	1.0	20.0
Lebanon	34187	1109	15	17.1	15.0	3.0	35.0
Lithuania	34825	1159	17	3.6	0.0	0.0	15.0
Oman	20482	1107	10	5.7	5.0	5.0	5.0
Paraguay	15430	1049	7	16.1	14.0	3.0	32.5
Russian	66731	1187	34	10.7	5.7	0.5	24.7
Saudi Arabia	62525	1202	32	12.1	12.0	12.0	12.0
Ukraine	37693	1128	18	7.4	5.0	0.0	15.0

(1) Varieties are defined as (6-digit HS, exporting country) pairs

Table 3: Inverse Export Supply Elasticity Statistics

	Inverse Export Supply Elasticity						Logs Regression (2)		
	Nobs	Vars per HS-4 (1)	Mean	Median	10th Perc	90th Perc	Beta	t-stat	R^2
Algeria	739	26	117.8	2.8	0.2	217.2	0.84	10.24	0.13
Belarus	704	20	84.8	1.5	0.1	152.7	0.84	10.28	0.14
Bolivia	639	21	103.4	2.0	0.1	217.2	0.77	7.94	0.09
China	1106	46	93.0	2.1	0.3	152.7	0.56	10.44	0.10
Taiwan	869	25	104.5	1.6	0.0	217.2	0.22	2.48	0.01
Czech	1075	42	63.4	1.4	0.1	90.9	0.72	12.91	0.14
Ecuador	747	25	77.5	1.5	0.1	148.8	0.77	9.29	0.11
Latvia	829	32	50.1	1.1	0.1	50.2	0.70	9.99	0.11
Lebanon	788	27	57.8	0.9	0.0	90.9	0.74	9.18	0.10
Lithuania	811	33	65.3	1.2	0.1	90.9	0.74	10.26	0.12
Oman	629	24	208.7	1.2	0.2	131.0	0.35	4.28	0.03
Paraguay	511	20	131.8	2.8	0.2	752.5	0.89	7.8	0.11
Russian	1032	54	47.6	1.8	0.2	90.9	0.57	10.35	0.10
Saudi Arabia	1036	53	70.6	1.7	0.2	131.0	0.53	8.64	0.07
Ukraine	861	32	84.1	2.1	0.2	152.7	0.80	11.29	0.13

(1) Median number of varieties per 4-digit HS code.

(2) Univariate regression of log inverse export supply elasticities in each country on the median of the log inverse elasticities in that good

Table 4A: Inverse Elasticities by Rauch Classification

	Differentiated	Reference Priced	Commodity
Median Inv Elasticity	2.73	0.82	0.71
	(0.06)	(0.02)	(0.09)
p-value (1)		0.000	0.000
Mean Inv Elasticity	86.67	67.57	14.23
	(0.26)	(3.60)	(0.56)
p-value (1)		0.202	0.000

Notes: Mean standard errors in parenthesis.
(1) p-values for means test of difference relative differentiated goods

Table 4B: Inverse Elasticities of Export Supply for the largest 15 4-digit HS sectors*

4-digit HS code	Inverse Elasticity (Median)	Nobs per ctry (median)	Import share	Description HS code
1201	0.0	13.5	0.023	SOYBEANS, WHETHER OR NOT BROKEN
1003	0.0	8	0.009	BARLEY
2711	0.1	20	0.032	PETROLEUM GASES & OTHER GASEOUS HYDROCARBONS
1001	0.1	10.5	0.013	WHEAT AND MESLIN
2304	0.2	11.5	0.006	SOYBEAN OILCAKE & OTH SOLID RESIDUE, WH/NOT GROUND
2710	0.3	42	0.013	OIL (NOT CRUDE) FROM PETROL & BITUM MINERAL ETC.
1511	0.3	10	0.006	PALM OIL & ITS FRACTIONS, NOT CHEMICALLY MODIFIED
2601	0.5	17.5	0.028	IRON ORES & CONCENTRATES, INCLUDING ROAST PYRITES
2709	0.6	27.5	0.309	CRUDE OIL FROM PETROLEUM AND BITUMINOUS MINERALS
1205	0.9	7	0.007	RAPE OR COLZA SEEDS, WHETHER OR NOT BROKEN
7108	1.3	12	0.009	GOLD (INCL PLAT PLATED), UNWR, SEMIMFR OR POWDER
8703	1.3	122	0.007	MOTOR CARS & VEHICLES FOR TRANSPORTING PERSONS
8401	2.8	10	0.010	NUCLEAR REACTORS; FUEL ELEM (N-I); MACH ISOTOP SEP
8802	46.5	18.5	0.020	AIRCRAFT, POWERED; SPACECRAFT & LAUNCH VEHICLES
8542	63.8	98.5	0.006	ELECTRONIC INTEGRATED CIRCUITS & MICROASSEMBL, PTS

* Import share is defined as the ratio of total imports for the 15 countries in an HS4 good relative to their total imports
All elasticities for the 15 non-WTO countries are included in this table.

Table 5: Inverse Export Supply Elasticities, GDP and World Import Shares

Dependent Variable	Log Inverse Export Supply purged by 4-digit fixed effects			
Sample:	All 15 non-WTO countries		Only 5 with production data	
Log GDP	0.149		0.099	
	(0.04)		(0.04)	
Share of World HS-4 Imports		6.52		9.35
		(1.56)		(2.13)
Constant	-3.04	0.662	-1.41	1.27
	(1.15)	(0.29)	(1.14)	(0.25)
Observations	12376	12372	4190	4190
R-squared	0.26	0.25	0.39	0.39

All regressions include 4-digit HS fixed effects. Standard errors in parentheses;
In the log GDP regressions, standard errors are clustered by country.
Share of world imports calculated for 2000

Table 6: Industry Fixed Effects

Dependent Variable	4-digit HS Average Tariff (%)					
Estimation Method	OLS	Tobit	IV	OLS	Tobit	IV
Inverse Export Elasticity	0.0005	0.0005	0.0017			
	(0.0002)	(0.0002)	(0.0026)			
Log Inverse Export Elasticity				0.436	0.468	0.474
				(0.055)	(0.054)	(0.109)
Observations	12333	12333	11801	12333	12333	11801
Number of HS 4-digit	1207	1207	1133	1207	1207	1133
R-squared	0.21			0.22		

Table 7: Country Fixed Effects

Dependent Variable	4-digit HS Average Tariff (%)								
Inv Export Elasticity Sample	Smaller than 25th percentile	Smaller than 50th percentile	Smaller than 75th percentile	All	All	All	All	All	All
Estimation Method	OLS	OLS	OLS	OLS	Tobit	OLS	OLS	OLS	Tobit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Inverse Export Elasticity	6.9671	2.115	0.028	0.0003	0.0003				
	(1.51)	(0.346)	(0.031)	(0.0001)	(0.0001)				
Dummy Mid and High Inv Exp Elast						1.2415			
						(0.246)			
Dummy Mid Inv Exp Elast							1.668		
							(0.285)		
Dummy High Inv Exp Elast							0.82		
							(0.280)		
Log Inverse Export Elasticity								0.1206	0.1242
								(0.043)	(0.046)
Algeria	18.74	20.25	23.27	23.8	23.78	23.01	23.01	23.66	23.63
	(1.08)	(0.75)	(0.56)	(0.47)	(0.50)	(0.50)	(0.50)	(0.48)	(0.51)
Belarus	9.76	11.01	12.1	12.38	12.28	11.57	11.57	12.3	12.2
	(1.06)	(0.72)	(0.57)	(0.49)	(0.52)	(0.51)	(0.51)	(0.49)	(0.52)
Bolivia	8.55	8.45	9.69	9.76	9.76	8.97	8.97	9.65	9.65
	(1.11)	(0.76)	(0.60)	(0.51)	(0.54)	(0.53)	(0.53)	(0.51)	(0.54)
China	30.55	34.66	38.05	37.88	37.79	37.08	37.08	37.74	37.65
	(0.95)	(0.62)	(0.46)	(0.38)	(0.41)	(0.42)	(0.42)	(0.39)	(0.41)
Taiwan	9.41	9.04	9.66	9.69	9.17	8.89	8.89	9.61	9.09
	(0.92)	(0.64)	(0.51)	(0.43)	(0.46)	(0.46)	(0.46)	(0.43)	(0.46)
Czech Republic	6.56	7.56	9.13	9.46	8.55	8.65	8.65	9.4	8.49
	(0.87)	(0.59)	(0.46)	(0.39)	(0.42)	(0.43)	(0.43)	(0.39)	(0.42)
Ecuador	7.91	8.89	10.03	9.81	9.78	9.00	9.00	9.73	9.70
	(1.02)	(0.70)	(0.55)	(0.47)	(0.50)	(0.50)	(0.50)	(0.47)	(0.50)
Latvia	6.21	7.27	7.56	7.26	6.99	6.45	6.45	7.24	6.97
	(0.94)	(0.64)	(0.51)	(0.44)	(0.47)	(0.47)	(0.47)	(0.44)	(0.47)
Lebanon	15.37	15.44	17.02	17.1	17.1	16.29	16.29	17.09	17.09
	(0.98)	(0.67)	(0.54)	(0.46)	(0.49)	(0.49)	(0.49)	(0.46)	(0.49)
Lithuania	3.17	3.34	4.00	3.62	-5.61	2.81	2.81	3.57	-5.65
	(0.99)	(0.67)	(0.53)	(0.45)	(0.59)	(0.48)	(0.48)	(0.45)	(0.59)
Oman	3.86	4.59	5.99	5.62	4.85	4.86	4.86	5.61	4.83
	(1.13)	(0.76)	(0.60)	(0.51)	(0.55)	(0.54)	(0.54)	(0.51)	(0.55)
Paraguay	12.68	13.85	15.79	16.09	16.03	15.3	15.28	15.93	15.86
	(1.26)	(0.87)	(0.70)	(0.57)	(0.61)	(0.59)	(0.59)	(0.57)	(0.61)
Russia	7.35	8.91	10.59	10.66	9.88	9.84	9.84	10.55	9.77
	(0.96)	(0.63)	(0.47)	(0.40)	(0.43)	(0.43)	(0.43)	(0.40)	(0.43)
Saudi Arabia	10.21	10.66	12.11	12.13	12	11.32	11.32	12.02	11.89
	(0.94)	(0.62)	(0.47)	(0.40)	(0.43)	(0.43)	(0.43)	(0.40)	(0.43)
Ukraine	6.08	5.9	7.36	7.36	6.19	6.55	6.55	7.23	6.06
	(1.10)	(0.74)	(0.56)	(0.48)	(0.52)	(0.50)	(0.50)	(0.48)	(0.52)
Observations	2968	6051	9158	12333	12333	12333	12333	12333	12333
R-squared	0.54	0.59	0.61	0.61		0.61	0.61	0.61	

Standard errors in parenthesis

Table 8:
Percent difference relative to mean country tariff

		Political Economy Dummy		
		Low	Medium	High
Inverse Export Supply Elasticity Dummy	Low	-34	-18	24
		(4.2)	(3.4)	(4.5)
	Medium	-22	1	34
		(3.2)	(3.6)	(4.1)
	High	-16	3.8	19
		(2.8)	(3.9)	(5.1)

Notes: Low<33rd percentile of variable within each country
Medium=33th - 66th; High: >66th all within each country. Average tariff in a category is the average over the countries of the percentage difference between the products in that cell and the mean in the country. Standard errors of the mean percent difference in parenthesis.
Political Economy Dummy constructed by country as (Production/Imports)/Import Demand Elasticity

Table 9 : Pooled regressions

Dependent Variable	HS 4-digit Average Tariff (%)					
Estimation Method	OLS	TOBIT	QREG	IV GMM (1)	OLS	IV GMM (2)
Medium Inv Export Elast	2.472	2.45	0.556	3.05		
	(0.559)	(0.560)	(0.003)	(0.567)		
High Inverse Export Elast	2.222	2.147	0.556	3.253		
	(0.578)	(0.577)	(0.004)	(0.590)		
Medium Inv Import Pen/Imp Ela	2.77	2.888	0.735	4		
	(0.525)	(0.562)	(0.003)	(1.157)		
High Inv Import Pen/Imp Elast	6.915	7.077	3.235	10.644		
	(0.563)	(0.576)	(0.004)	(0.763)		
Log (Inv Export Elast)					0.34	0.52
					(0.078)	(0.081)
Log (Inv Import Pen/Imp Elast)					1.27	2.179
					(0.100)	(0.145)
Bolivia	4.995	4.934	8.265	2.805	11.428	12.681
	(0.520)	(0.764)	(0.004)	(0.672)	(0.208)	(0.306)
China	32.375	32.288	27	30.184	35.383	34.199
	(0.942)	(0.690)	(0.004)	(0.985)	(0.821)	(0.824)
Taiwan	4.686	4.208	5.765	2.495	9.623	9.78
	(0.583)	(0.715)	(0.004)	(0.705)	(0.279)	(0.293)
Ecuador	5.291	5.193	7.765	3.101	11.096	11.877
	(0.540)	(0.739)	(0.004)	(0.679)	(0.216)	(0.250)
Latvia	2.389	2.043		0.197	8.809	9.997
	(0.601)	(0.728)		(0.727)	(0.388)	(0.415)
Constant			0.444			
			(0.004)			
Observations	3797	3797	3797	3797	3791	3791
R-squared	0.69				0.68	

Notes: Robust standard errors in parenthesis.
(1) Medium and high import penetration dummies instrumented by average
and high import penetration dummies based on import penetration dummies of other countries.
(2) Inv Import Pen portion of Log (Inv Import Pen/Imp Elast) is instrumented with the mean for remaining four countries

Table 10: Regressions by Country

Dependent Variable	HS 4-digit Average Tariff (%)									
Country	China	Ecuador	Taiwan	Latvia	Bolivia	China	Ecuador	Taiwan	Latvia	Bolivia
Estimation Method	OLS	OLS	OLS	OLS	OLS	IV	IV	IV	IV	IV
Constant	27.113	5.613	7.43	2.943	9.435	20.637	6.646	5.959	2.195	9.368
	(1.797)	(0.426)	(0.819)	(0.714)	(0.101)	(2.073)	(0.558)	(0.763)	(1.096)	(0.118)
Medium Inv Export Elast	7.064	1.756	-0.043	1.785	-0.141	8.012	1.546	0.476	2.083	-0.126
	(2.025)	(0.433)	(0.687)	(0.857)	(0.078)	(2.104)	(0.445)	(0.670)	(0.897)	(0.072)
High Inverse Export Elast	5.405	1.318	1.21	1.237	0.076	7.654	1.027	2.062	1.904	0.104
	(2.052)	(0.454)	(0.821)	(0.824)	(0.066)	(2.110)	(0.467)	(0.802)	(0.890)	(0.065)
Medium Inv Import Pen/Imp Elast	4.749	3.645	1.476	1.826	0.558	10.947	1.932	2.339	0.281	0.598
	(1.914)	(0.457)	(0.706)	(0.682)	(0.089)	(4.481)	(1.089)	(1.026)	(1.767)	(0.171)
High Inv Import Pen/Imp Elast	12.936	6.699	3.504	7.874	0.563	22.95	5.812	5.682	10.703	0.682
	(1.997)	(0.435)	(0.742)	(0.848)	(0.093)	(2.597)	(0.685)	(1.002)	(1.139)	(0.123)
Observations	931	698	805	750	613	931	698	805	750	613
R-squared	0.05	0.24	0.03	0.11	0.12					

Notes: Robust standard errors in brackets.

Appendix: Optimal tariff with CES utility for foreign varieties

Broda-Weinstein (2005) assume the existence of a utility $M^{\mu}D^{\alpha}$ where M is the subutility function for imported goods and D is a composite domestic good. Therefore we follow that approach here but rule out income effects by using the quasilinear structure outlined in the text with $u = u(M^{\mu}D^{\alpha})$. Moreover, we take M as a Cobb-Douglas aggregate over imported goods $g \in G_m$, so $M = \prod_g M_g^{\phi_g}$. Each M_g is in turn composed of varieties that are aggregated via a CES utility with elasticity of substitution $1/(1-\rho_g)$. So $M_g = (\Sigma_v d_{gv}^{1-\rho_g} m_{gv}^{\rho_g})^{1/\rho_g}$ where $d_{gv} > 0$ is a taste or quality parameter for gv. Finally, we assume that the subutility represented by u gives rise to constant expenditure. That is $u = \ln(M^{\mu}D^{\alpha})$. Thus we can rewrite the utility as

$$U = c_0 + \mu \sum_{g \in G_m} \phi_g \ln[(\Sigma_v d_{gv}^{1-\rho_g} m_{gv}^{\rho_g})^{1/\rho_g}] + \alpha \ln D \; ; \; 0 < \rho_g < 1 \tag{1}$$

This structure implies separability across imported goods but not its varieties. We could provide a similar treatment to the domestic composite good but since it is log separable this is not necessary in order to determine the optimal tariffs for each imported good. As shown in the standard model in the text a demand structure with quasilinear utility and separability over goods g implies that tariffs in any good g only impact welfare through the consumption of that good and the tariff revenue it generates. Thus we can focus on deriving the optimal tariff separately for each good $g \in G_m$. Furthermore we assume that $\tau_{gv} = \tau_g$ for all v in a given good, as generally observed in the data.

We now show that the optimal tariff for each of these goods is given by the inverse export supply elasticity as we estimate it. In the estimation we must assume they are constant and identical within goods across imported varieties. Therefore we impose those conditions and write the export supply for each variety of good g as

$$m_{gv}^* = a_{gv} p_{gv}^{*1/\omega_g} \text{ all } g, v \tag{2}$$

Note that different exporters may have different a_{gv} and this variation, along with the differences in demand taste generate variation in prices across exporters that is important in identifying the elasticities empirically (we also use the time variation). The demand for each variety is obtained by minimizing expenditure subject to obtaining a given level M_g. It is

$$\begin{aligned} m_{gv} &= d_{gv}(\frac{p_g}{p_{gv}})^{\sigma_g} M_g \\ &= \mu \phi_g d_{gv} p_{gv}^{-\sigma_g} p_g^{\sigma_g - 1} \end{aligned} \tag{3}$$

where p_g represents the standard price index, $\left(\sum_v d_{gv} p_{gv}{}^{1-\sigma_g}\right)^{1/(1-\sigma_g)}$. The second line uses the fact that $u()$ has a constant expenditure share and that the maximization of that utility will yield $p_g M_g = \mu\phi_g$. Using this and the export supply equation we obtain the market clearing price obtained by foreign exporters, $p^*_{gv} = p_{gv}/(1+\tau_{gv})$.

$$H\mu\phi_g d_{gv}(p^*_{gv}(1+\tau_g))^{-\sigma_g} p_g^{\sigma_g - 1} = a_{gv} p^{*1/\omega_g}_{gv} \tag{4}$$

$$p^*_{gv} = [\varphi_{gv}(1+\tau_g)^{-\sigma_g} p_g^{\sigma_g-1}]^{\frac{\omega_g}{1+\omega_g\sigma_g}} \tag{5}$$

where $\varphi_{gv} \equiv \frac{H\mu\phi_g d_{gv}}{a_{gv}}$ depends on variety specific characteristics so prices of the same will vary across exporters.

The key insight to showing that the optimal tariff equals ω_g is to note that the tariff does not affect the relative demand of varieties in any given good. Therefore the only distortion that it addresses is the terms of trade externality. There are three assumptions that explain this. First, consumption and export supply elasticities within a good are constant. Second they are identical across varieties or exporters of that good. Third, tariffs are equal across exporters of the same good. To see this we can simply use the expressions for m_{gv} and p^*_{gv} to obtain the relative demand across any two v, k of a given good as

$$\frac{m_{gv}}{m_{gk}} = \frac{d_{gv}}{d_{gk}}\left(\frac{\varphi_{gk}}{\varphi_{gv}}\right)^{\frac{\omega_g\sigma_g}{1+\omega_g\sigma_g}} \tag{6}$$

To obtain individual prices, p^*_{gv}, as a function of tariffs we first solve for the aggregate price index of each good and then replace it in the expression for p^*_{gv}. To do so we first note that $p_g = (1+\tau_g)\left(\sum_v d_{gv} p^*_{gv}{}^{1-\sigma_g}\right)^{1/(1-\sigma_g)}$ and then aggregate the individual prices from the market clearing conditions to obtain an expression similar to this one, which can be solved to obtain

$$p_g(\tau_g) = (1+\tau_g)^{\frac{1}{1+\omega_g}}\Phi \tag{7}$$

where $\Phi \equiv \left(\sum_v d_{gv}[\varphi_{gv}]^{\frac{\omega_g(1-\sigma_g)}{(1+\omega_g\sigma_g)}}\right)^{(1+\sigma_g\omega_g)/(1+\omega_g)(1-\sigma_g)}$. We can verify that if $\omega_g = 0$ there is complete pass-through from tariffs to the aggregate price of g and as ω_g increases the effect of tariffs to domestic prices is attenuated. Replacing this in the market clearing condition for each variety we obtain $p^*_{gv}(\tau_g)$.

$$p^*_{gv} = (1+\tau_g)^{-\frac{\omega_g}{1+\omega_g}}[\varphi_{gv}\Phi^{\sigma_g-1}]^{\frac{\omega_g}{(1+\omega_g\sigma_g)}} \tag{8}$$

The equilibrium imports as a function of tariffs is then $Hm_{gv} = m^*_{gv}$, for each variety of g given by

$$m^*_{gv}(\tau_g) = (1+\tau_g)^{-\frac{1}{1+\omega_g}}\Gamma_{gv} \tag{9}$$

$\Gamma_{gv} \equiv a_{gv}[\varphi_{gv}\Phi^{\sigma_g-1}]^{\frac{1}{1+\omega_g\sigma_g}}$

The government will then choose τ_g for each good to maximize the following social welfare expression

$$\max_{\tau_{gg}} W = H + \sum_g HW_g + \pi_d + Hs_d \tag{10}$$

where for each good g we have that W_g is given by $\tau_g \Sigma_v p^*_{gv}(\tau_g) m_{gv}(\tau_g) + \mu\phi_g \ln[(\Sigma_{gv} d_{gv}^{1-\rho} m_{gv}(\tau_g)^\rho)^{1/\rho}] - \Sigma_{gv} p_{gv}(\tau_g) m_{gv}(\tau_g)$. The foc for each good g can then be derived and simplified to obtain

$$\Sigma_v \left(\tau_g p^*_{gv} \frac{dm_{gv}}{d\tau_g} - m_{gv} \frac{dp^*_{gv}}{d\tau_g} \right) = 0 \tag{11}$$

Therefore we obtain an expression similar to the one in the text under the standard model. However, now it is defined over the sum of the varieties. To see that the elasticity we estimate is exactly the solution we can rewrite the expression above in terms of elasticities of m_{gv} and p^*_{gv} wrt τ_g. Using the equilibrium level of imports and prices derived it is simple to see that these are constant across varieties in a good and thus we obtain the inverse elasticity solution.

$$\begin{aligned} H\Sigma_v p^*_{gv} m_{gv} \left(\frac{dm_{gv}}{d\tau_g} \frac{\tau_g}{m_{gv}} - \frac{dp^*_{gv}}{d\tau_g} \frac{\tau_g}{p^*_{gv}} \frac{1}{\tau_g} \right) &= 0 \\ \Sigma_v p^*_{gv} m_{gv} \left(-\frac{1}{1+\omega_g} \frac{\tau_g}{1+\tau_g} - (-\frac{\omega_g}{1+\omega_g} \frac{\tau_g}{1+\tau_g}) \frac{1}{\tau_g} \right) &= 0 \\ \tau_g &= \omega_g \text{ all } g \end{aligned} \tag{12}$$