Estimating Policy Barriers to Trade

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Abstract

To what extent is international trade free and fair? Because policy barriers to trade are often opaque and take on many forms, it is difficult to answer this question while relying on data on observable trade barriers. Here, I propose and implement a structural approach to estimating the magnitude of policy barriers to trade, measured at the trade partner level. The method allows for the possibility that these barriers are both *asymmetric* and *discriminatory*, affecting certain trade partners disproportionately. The approach reveals substantial latent policy barriers to trade, many times larger than observed tariffs. It also implies substantial effective policy discrimination, with exporters in subset of favored countries enjoying far superior market access conditions than their peers in unfavored countries. Combined, these results suggest that the existing world trading system remains far from a free and fair ideal.

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Introduction

Is international trade free and fair? For trade to be free, firms must not face government-imposed burdens to foreign market access. I refer to these burdens as policy barriers to trade. For trade to be fair, any policy barriers that do exist must treat products from all origin countries equally.[1]

Examining tariff rates produces a qualified "yes," on both counts. Despite recent threats to the world trading system,[2] tariffs remain at historically low rates (less than five percent on most trade (Baldwin 2016)), suggesting trade is relatively free. Moreover, World Trade Organization (WTO) member countries, accounting for the vast majority of the world economy, commit to the principle of nondiscrimination (or most-favored-nation (MFN)) in tariff policy, applying the same tariff rates to the imports of all member countries. At first glance, adherence to this principle suggests international trade is also fair.

However, tariffs are but one instrument by which governments can influence the flow of trade. *Direct* barriers to trade are imposed at national borders or ports of entry. In addition to tariffs, governments also impose many non-tariff regulations on imports. Often referred to collectively as nontariff measures (NTMs), these regulations require that prospective importers comply with these price controls, quotas, quality and safety requirements, and other rules in order to access foreign markets.[3]

Indirect, or "behind-the-border", barriers are economic policies not assessed at the border that nevertheless disproportionately affect imported goods. Government procurement rules often explicitly privilege domestic suppliers, resulting in increased domestic purchases and reduced imports (Evenett and Hoekman 2004; Kono and Rickard 2014). Excise taxes, while implemented uniformly on a single good, may primarily fall on imports if targeted at goods with high foreign content.[4] Subsidies and tax credits made available to domestic firms allow less productive firms to survive, supplanting importers in home markets and reducing trade. The burden of complying with health, safety, and environmental regulations may also fall disproportionately on foreign firms, reducing their sales and distorting trade.

All of these instruments can in principle be targeted to generate *de facto* discrimation. For example, the MFN principle is enforced at the tariff line level, allowing importers to target duties at products exported by specific countries, without running afoul of WTO rules. Through high agricultural duties, the United States, Europe, and Japan effectively discriminate against the developing world, which specializes in the production of these

[1] Of course, there are many competing conceptions of what a free and fair international trading system should look like. These are the definitions of free and fair I use here.

[2] See Bown, Chad P. "Is the Global Trade System Broken?" *Peterson Institute for International Economics.* 8 May 2018.

[3] For studies of these kinds of barriers, see Edward D. Mansfield and Busch (1995); Lee and Swagel (1997); Gawande and Hansen (1999); Kono (2006); Rickard (2012); Maggi, Mrázová, and Neary (2018).

[4] Sin taxes on alcohol and cigarettes might distort trade if these products are generally imported.

products (K. Anderson and Martin 2005). NTMs and behind-the-border barriers can produce effective discrimination in the same manner.

Even armed with data on all such trade-distorting policy instruments, estimating the magnitude of aggregate policy barriers to trade would be challenging. Here, I propose and implement a new method to estimate policy barriers to trade with minimal data requirements. I construct a parsimonious model of international trade subject to frictions, following Eaton and Kortum (2002).[5] I show that the magnitude of trade frictions between two countries i and j is related by the theoretical model to price levels in both countries, trade flows between them, and the market shares of domestic producers in home markets. I then decompose these barriers into their economic (transportation costs) and political (policy barriers) components. Finally, I calibrate this relationship to the data on prices, trade, and freight costs in 2011.

The intuition underlying the model is straightforward. Cross-national price gaps inform about the existence of arbitrage opportunities, and imply that large trade flows should exist from countries with low prices toward those with high prices. The extent to which these flows are realized in the data informs about the magnitude of trade costs. If the cost of freight between countries is known, than the component of these costs than cannot be attributed to purely economic frictions can be independently identified. The remaining "missing trade" is attributed to the existence of policy distortions, broadly defined.

The logic behind the approach employed here is also articulated in Leamer (1988). If consumers are homogenous across countries, they will consume the same basket of goods when trade is frictionless (and prices equalize across markets).[6] Observered heterogeneity in consumption baskets is then informative about the magnitude of trade frictions. Leveraging advances in the structural gravity literature, I am able to empirically connect Leamer's basic insight more tightly to theory.

The results point to far more policy distortion and effective discrimination than would be inferred from the tariff data. Tariff equivalents of implied policy barriers are generically more than an order of magnitude larger than observed tariffs. Moreover, exporters in subset of favored countries enjoy far superior market access counditions than their peers in unfavored countries.

The trade policy openness attributed to developed countries also depends strongly on the metric used to evaluate openness.[7] As shown in Figure 1, there is a negative association

[5] Theirs is a Ricardian model, in which the basis for trade emerges from differences in technologies across countries.

[6] Empirical studies of trade rely heavily on the (dubious) assumption of consumer homogeneity. For a prominent counterexample, see Fajgelbaum and Khandelwal (2016). I hold consumers' preferences over tradable goods constant, but allow for heterogeneity in consumers' taste for tradable versus nontradable goods.

[7] See Rodríguez and Rodrik (2000), Dollar and Kraay (2004), and Tavares (2008) for discussions of this phenomenon.

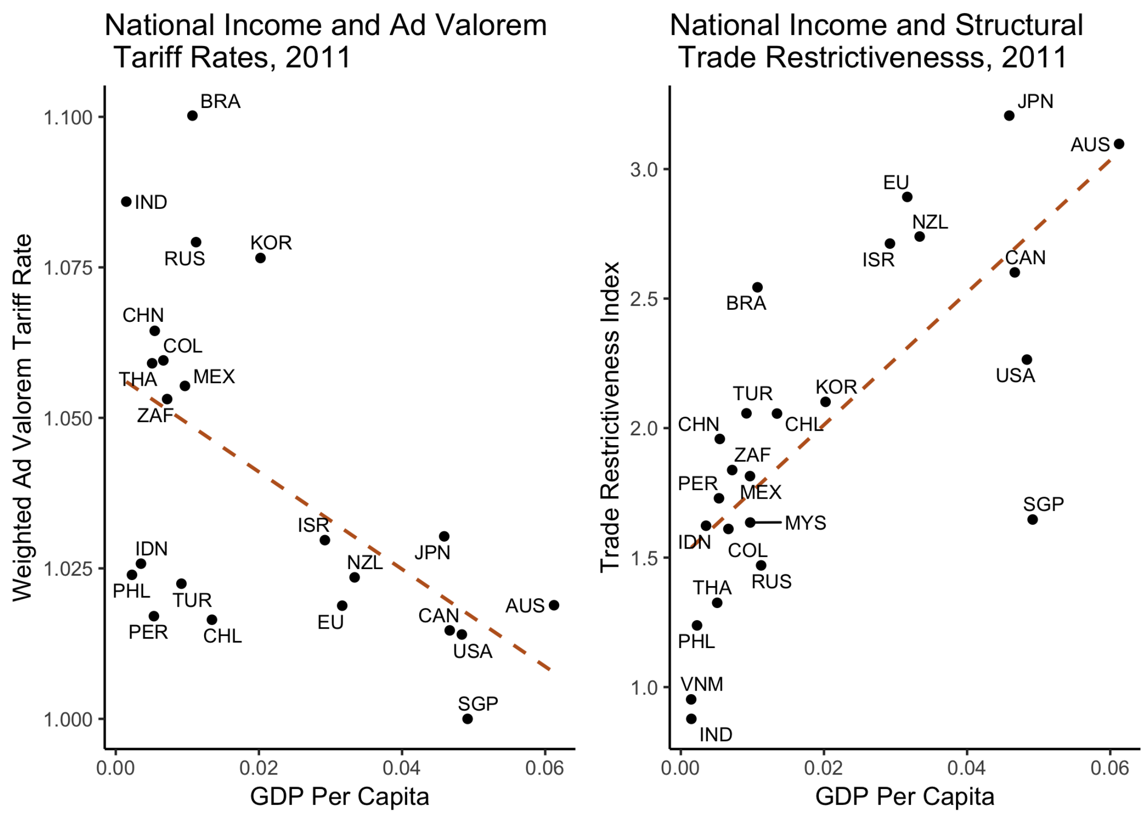

Figure 1: Tariff rates (left) and structural trade restrictiveness (right) against GDP per capita

between economic development (per capita GDP) and applied tariff rates. This relationship is reversed if trade policy restrictiveness is measured as proposed here. Countries with higher per capita incomes tend to have higher Trade Restrictiveness Indices.[8] This is consistent with Kono (2006) and Queralt (2015), which suggest that developed countries offset tariff reductions with increases in non-tariff direct barriers and (potentially distortionary) domestic taxes.

This paper is most closely related to the international economics literature on the estimation of trade costs, beginning with J. E. Anderson and Van Wincoop (2004). The particular methodology adopted here draws on several studies that link price gaps to these trade costs (Eaton and Kortum 2002; Waugh 2010; Simonovska and Waugh 2014; Sposi 2015; Waugh and Ravikumar 2016). I build on these studies by disentangling policy barriers to trade and freight costs, and connecting the implied policy barriers to observable trade policy instruments. A parallel literature focuses on the estimation of trade costs under the assumption that they are symmetric (Head and Ries 2001; Novy 2013).[9] While trans-

[8] See Equation 17.

[9] Bergstrand, Egger, and Larch (2013) provide an alternative method to estimate the asymmetric barriers targeted here.

portation costs may be nearly symmetric, policy barriers are less likely to be (Kono 2008; Tavares 2008). Such estimates therefore average over meaningful policy heterogeneity.

The paper is also related to efforts to use observable barriers to trade to construct indices of trade openness (Sachs and Warner 1995; J. E. Anderson and Neary 1996; Kee, Nicita, and Olarreaga 2009). These observable barriers may be a non-random sample from the universe of protectionist instruments, however. Here, I take advantage of the structure of the theoretical model to infer the magnitude of policy barriers from the price and trade data, rather than attempting to quantify observable barriers. Hiscox and Kastner (2002) construct country-level measures of aggregate trade openness using a fixed effects approach. Martini (2018) constructs industry-level measures of trade restrictiveness, under the assumption that policy barriers are nondiscriminatory within industry. I sacrifice industry-level granularity in order to assess discrimination in the international trade policy regime.

The fields of comparative and international political economy rely heavily on imperfect measures of trade protectionism. Political economic theories of protectionism generally relates primitives of the economic and political environment to a government's choice of trade policy, broadly construed. In evaluating these theories, however, researchers generally resort to examining observable barriers to trade, such as applied tariff rates, NTM coverage ratios, or simply the volume of trade.[10] The measure constructed here is arguably closer to the theoretical quantity of interest of many of these studies.

The broad policy barriers recovered here are also the objects that governments seek to influence in international negotiations, particularly in today's era in which tariffs rates are historically low.[11] Governments desire foreign market access for the firms whose interests they represent (Gawande, Krishna, and Olarreaga 2009; Ossa 2011; Ossa 2012). Acquiring foreign market access requires dismantling policy barriers to trade, direct and indirect. This places governments in a complex multilateral bargaining game that has attracted the attention of many studies.[12] Evaluating and assessing the outcomes of this game requires measurement of its outcomes – governments' trade policy choices.

Finally, many argue that international institutions, the WTO and its predecessor General Agreements on Tariffs and Trade (GATT) in particular, structure this bargaining game in important ways (Bagwell and Staiger 1999; Maggi 1999; Steinberg 2002; Davis 2006; Carnegie 2014; Bagwell, Staiger, and Yurukoglu 2018). GATT signatories committed in

[10]For a few examples, see Goldberg and Maggi (1999); Edward D Mansfield, Milner, and Rosendorff (2000); Milner and Kubota (2005); Tavares (2008); Kono (2009); Gawande, Krishna, and Olarreaga (2009); Betz (2017); Barari, Kim, and Wong (2019).

[11]For example, Trans Pacific Partnership (TPP) negotiations focused overwhelmingly on non-tariff liberalization efforts. Fergusson, Ian F. and Brock R. Williams. "The Trans-Pacific Partnership (TPP): Key Provisions and Issues for Congress." 14 June, 2016. Congressional Research Service.

[12]See, for example, Hirschman (1945); Pollins (1989); Gowa and Mansfield (1993); Milner (1997); Aghion, Antràs, and Helpman (2007); Head, Mayer, and Ries (2010); Antràs and Padró i Miquel (2011); Dube, Kaplan, and Naidu (2011); Berger et al. (2013); Ossa (2014).

principle to convert protective policy measures into tariff-equivalents and subsequently negotiated primarily over tariff barriers (Bagwell and Staiger 2004). Theories of international trade institutions generally take this commitment seriously, assuming commitments to reduce tariffs cannot be subsequently "undone" through the implementation of non-tariff or behind-the-border barriers to trade. Statements about the efficacy of the principles of reciprocity and nondiscrimination in achieving efficient outcomes rest on this premise.

I proceed in three steps. The next section specifies a model of international trade and demonstrates how it relates observables to the magnitude of trade policy distortions. I then discuss the data that I use to calibrate the model. Finally, I present the results of this exercise and discuss their implications for the question posed at the beginning of this paper – is international trade free and fair?

Model

In 2011, tradable goods were, on average, twice as expensive in Japan than in Malaysia.[13] If trade were frictionless, Malaysian merchants could exploit this price difference by shipping goods to Japan, making more than twice what they would be selling their goods in their home market. Factually, however, Malaysian exporters made up less than one percent of the market for tradables in Japan in 2011. The model explicated below allows me to infer that these prospective exporters must have faced high costs to sell in the Japanese market and to quantify the exact magnitude of these costs. If freight costs are known, then the component of these costs attributable to policy distortions can be recovered separately.

Eaton and Kortum (2002) and Waugh (2010) show that these forces are related in a simple equation. Let $d_{ij} \geq 1$ denote the iceberg cost of shipping goods from j to i,[14] λ_{ij} denote j's market share in i, and P_i denote the aggregate price of tradables in i. Then,

$$d_{ij} = \left(\frac{\lambda_{ij}}{\lambda_{jj}} \right)^{-\frac{1}{\theta}} \frac{P_i}{P_j} \tag{1}$$

where $\theta > 1$ is the trade elasticity.[15] This equation has intuitive comparative statics. If aggregate prices are equal in both markets ($P_i = P_j$), then j's relative market penetration informs directly about trade barriers. As λ_{ij} goes up, the implied barrier d_{ij} goes down. When j's share in i's market is equivalent to its share in its own market ($\lambda_{ij} = \lambda_{jj}$), we infer that j faces no barriers to export to i ($d_{ij} = 1$).[16] Now, assume that aggregate prices

[13] See The World Bank, International Comparison Program (ICP)

[14] By the iceberg assumption, for every d_{ij} units shipped from j to i, 1 unit arrives. $d_{ij} - 1$ is the ad valorem value of the aggregate tax firms in j face to export to i.

[15] Here, λ_{jj} is the share of j's market for tradables that is captured by producers within j.

[16] This is a natural result of the assumption of consumer homogeneity.

in i and j differ. Specifically, let $P_i > P_j$. In the absence of trade costs, this would generate an arbitrage opportunity for producers in j – they can profit by shipping goods to i and taking advantage of higher prices. If trade were frictionless, then we must have $(\lambda_{ij} > \lambda_{jj})$. The extent to which this relationship holds in the data informs about the magnitude of barriers to trade.

This relationship between cross national tradable prices, trade flows, and trade costs follows from the competitive framework of Eaton and Kortum (2002), adapted to the study of trade costs by Waugh (2010). In the model presented below, I modify their underlying framework in order to minimize the conceptual distance between the theory and the data. However, the result is not unique to competitive international economies. Quantitative trade models with market imperfections generate related "gravity" equations that imply the same relationship between prices, trade, and trade costs (Melitz 2003; Chaney 2008; Costinot and Rodríguez-Clare 2015).

Environment

There are N countries in the international economy, indexed $i \in \{1, ..., N\}$. Within each country resides a representative consumer, with labor endowment L_i. The setup follows closely Eaton and Kortum (2002), so I omit some derivations of the quantities presented here and direct readers to their paper. To match the data on consumer expenditure on tradable goods, I consider a variant their model which consumers value both tradable goods and nontradable services. Then, gross consumption of tradables in the economy is simply gross consumption (including final and intermediate goods) minus consumer expenditure on services. This is the denominator I use in calculating trade shares when calibrating the model.

Consumption

Each consumer values aggregate tradable goods Q_i and aggregate nontradable services S_i, which are combined in a Cobb-Douglas utility function

$$U_i = Q_i^{\nu_i} S_i^{1-\nu_i} \tag{2}$$

A country-specific parameter $\nu_i \in [0, 1]$ governs the consumer's relative preference for goods over services. Wages are denoted w_i, which implies country gross domestic products are given by

$$I_i = w_i L_i$$

Cobb-Douglas preferences imply consumers will spend a fraction ν_i of their income on tradable goods.[17] Equilibrium consumer expenditure on tradables is then

$$E_i^q = \nu_i I_i + D_i$$

where D_i is the value of exogenously given trade deficits.

There is a continuum of tradable varieties, indexed by $\omega \in [0, 1]$. There is a set $\mathcal{K}$ of tradable good categories indexed $k \in \{0, ..., K-1\}$. Let

$$h : \Omega \to \mathcal{K}$$

be a function that associates varieties with good categories. The set of goods in category k is Ω_k where

$$\Omega_k = \{\omega : h(\omega) = k\}$$

The mass of each tradable good category is $1/K$. Consumers' preference for goods in category k is given by $\alpha_k \geq 0$ and is constant across countries.

Consumer utility over these varieties exhibits constant elasticity of substitution (CES)

$$Q_i = \left(\int_{[0,1]} \alpha_{h(\omega)}^{\frac{1}{\sigma}} q_i(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}} \tag{3}$$

with $\sigma > 0$. With expenditure on tradables fixed by the Cobb Douglas upper level preference structure, consumers simply maximize Q_i subject to their tradable budget constraint, $\int_{[0,1]} p_i(\omega) q_i(\omega) d\omega \leq E_i^q$, where $p_i(\omega)$ is the (endogenous) price of variety ω in country i. The aggregate price of tradables in country i is as in Dixit and Stiglitz (1977)

$$P_i = \left(\int_{[0,1]} \alpha_{h(\omega)} p_i(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}} \tag{4}$$

Production

Every country can produce every tradable variety ω. Each country has an underlying mean productivity level T_i, but ω-specific productivites $z_i(\omega)$ are modeled as the realization of a random variable drawn from a Frechet distribution. Production requires both labor and a composite intermediate good that is exactly analagous to an aggregate consumption good Q_i. The cost of producing a unit of variety ω is

$$c_i = w_i^{1-\beta} P_i^{\beta} \tag{5}$$

[17] In calibrating the model, I choose ν_i to match the factual expenditure shares on tradables in each country, as reported by the ICP.

where the global parameter $\beta \in [0, 1]$ governs the share of intermediates required in production.[18] Let X_i denote the value of tradable production in country i. A constant share, β, of this value will be spent on intermediates

$$E_i^x = \beta X_i$$

Countries require $1/z_i(\omega)$ labor-intermediate bundles to produce one unit of variety ω. Markets are competitive, so prices are equal to marginal costs. The local price ($p_{ii}(\omega)$) of variety ω is therefore

$$p_{ii}(\omega) = \frac{c_i}{z_i(\omega)} \tag{6}$$

ω-specific productivities are stochastic. Let $F_i(z)$ denote the probability that country i's productivity is less than or equal to z, formally

$$F_i(z) = \Pr \{z_i(\omega) \leq z\}$$

When $F_i(z)$ is distributed Frechet, then

$$F_i(z) = \exp \left\{-T_i z^{-\theta}\right\} \tag{7}$$

The country-wide technology level T_i shifts country i's productivity distribution – higher values of T_i imply higher productivity values on average. $\theta > 1$ is a global parameter that governs the variance of the productivity draws.[19]

Exporters pay iceberg costs ($d_{ji} \geq 1$) to ship goods abroad. The price in country j of varieties produced in i is therefore

$$p_{ji}(\omega) = d_{ji} p_{ii}(\omega)$$

These costs are affected by transportation infrastructure at home and abroad, international freight costs, and policy distortions. Below, I present a framework for disentangling these costs and isolating the magnitude of distortions attributable to policy.

Domestic consumers and producers alike search around the world for the cheapest source of each variety ω. The equilibrium price of variety ω in country i must satisfy

$$p_i^\star(\omega) = \min_{j \in \{1,...,N\}} \{p_{ij}\}$$

[18] Services are produced at cost $c_i^s = \frac{w_i}{A_i}$, where A_i is a country-specific services productivity.

[19] In equilibrium, it serves as the elasticity of trade flows to trade costs. As producers become more heterogeneous, trade becomes more sensitive to changes in costs.

Equilibrium

For national accounts to balance, gross output and gross consumption, inclusive of trade deficits D_i, must be equal.

$$I_i + \beta X_i = E_i^q + E_i^x + (1-\nu_i) I_i + D_i \tag{8}$$

Total income is given by the sum of domestic payments for services and labor payments from the global sales of tradables, X_i

$$I_i = w_i L_i = (1-\beta) X_i + (1-\nu_i) I_i$$

Substituting into Equation 8 requires

$$X_i = E_i^q + E_i^x - D_i \tag{9}$$

or that trade less deficits is balanced.

Total expenditure on tradables is the sum of expenditures from consumers and producers[20]

$$E_i = E_i^q + E_i^x$$

Let $\lambda_{ij}(\boldsymbol{w})$ denote the share of expenditure on tradables country i spends on goods from j and

$$\Omega_{ij}^{\star} = \left\{ \omega \in [0,1] \mid p_{ij}(\omega) \leq \min_{k \neq j} \{p_{ik}\} \right\}$$

Then

$$\lambda_{ij}(\boldsymbol{w}) = \frac{1}{E_i} \int_{\Omega_{ij}^{\star}} p_{ij}(\omega) q_i \left(p_{ij}(\omega)\right) d\omega \tag{10}$$

where $q_i\left(p_{ij}(\omega)\right)$ is equilibrium consumption of variety ω from both producers (intermediates) and consumers (final goods).

This quantity depends on wages everywhere, stored in the vector $\boldsymbol{w} = \{w_1, ..., w_N\}$. Note that given exogenous labor endowments (L_i), trade costs (d_{ij}), technologies (T_i), and parameters $\{\sigma, \theta, \nu_i, \beta\}$, endogenous wages completely determine the pattern of trade. Gross income in country i from the sale of tradables can be written

[20] Note that expenditure on tradables can be written

$$E_i = I_i + \beta X_i - (1-\nu_i) I_i$$

which is simply gross output less consumer expenditure on services. This is the empirical quantity for E_i I use when calibrating the model.

$$X_i = \sum_{j=1}^{N} \lambda_{ji}(\boldsymbol{w}) E_j \tag{11}$$

Definition: An *international equilibrium* is a vector of wages $\boldsymbol{w}$ such that Equations 9, 10, and 11 hold for all $i \in \{1, ..., N\}$.

Alvarez and Lucas (2007) provide an argument for the existence and uniqueness of such an equilibrium. In the unique equilibrium, trade shares satisfy

$$\lambda_{ij}(\boldsymbol{w}) = \frac{T_j \left(d_{ij} w_j^{1-\beta} P_j^{\beta} \right)^{-\theta}}{\Phi_i} \tag{12}$$

where

$$\Phi_i = \sum_j T_j \left(d_{ij} w_j^{1-\beta} P_j^{\beta} \right)^{-\theta}$$

The equilibrium price index in country i is

$$P_i = \gamma \Phi_i^{-\frac{1}{\theta}} \tag{13}$$

where γ is a function of exogenous parameters.[21]

The numerator of Equation 12 is a measure of the overall competitiveness of country j. Naturally, increasing average productivity increases j's market penetration everywhere. Decreasing wages in j has the same effect. Decreasing trade costs between i and j (d_{ij}) also increases λ_{ij}. The denominator is a "multilateral resistance" (J. E. Anderson and Van Wincoop 2003) term that captures the overall level of competitiveness in country i. All else equal, it is easier to penetrate the market in country i if others struggle to penetrate it, due to inferior technology, high wages, and/or high bilateral trade costs.

Isolating Policy Barriers

To get from the factory gates of a firm located in an exporting country and the market located overseas, goods incur a bevy of costs, both economic and political in nature. Our goal is to recover the proportion of these costs attributable to *policy* barriers to trade. I assume that trade costs are multiplicatively decomposable into exporter-specific

[21] Specifically,

$$\gamma = \Gamma \left(\frac{\theta + 1 - \sigma}{\theta} \right)^{\frac{1}{1-\sigma}}$$

and Γ is the gamma function.

costs,[22] international freight costs, and policy barriers to trade. Note that I do not model heterogeneity in costs common to all traders within *importing* countries. This framework yields

$$d_{ij} = \rho_j \delta_{ij}(\boldsymbol{Z}_{ij}) \tau_{ij} \tag{14}$$

where ρ_j denotes exporter-specific costs, δ_{ij} denotes international freight costs, and τ_{ij} denotes policy barriers. δ_{ij} is a function, which takes a vector of bilateral geographic covariates $\boldsymbol{Z}_{ij}$ and outputs bilateral freight costs.[23] I normalize $\delta_{ii} = \tau_{ii} = 1$.

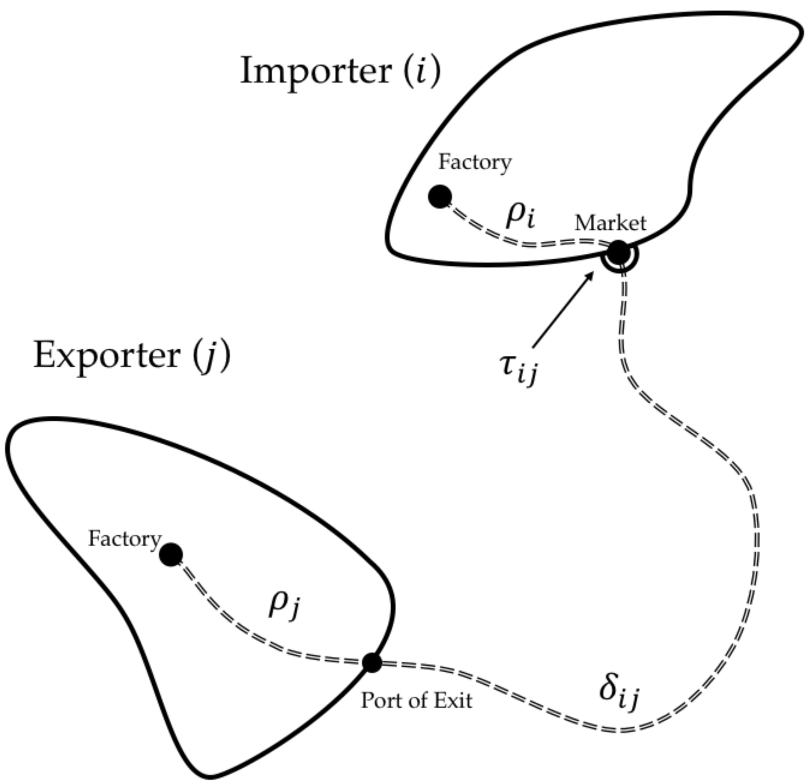

Figure 2: Trade cost decomposition.

Figure 5 traces the path goods must travel from a factory in country j to a market in country i. Goods first travel from the factory in j to j's border. Upon reaching the border (airport, port, or border crossing), goods must travel by land, sea, or air to the border of their destination country. Along the way, they incur freight costs δ_{ij}. The market in i is

[22]This includes both costs associated with transportation within the exporting country and any taxes and regulatory costs that are common to all traders in the country (Limao and Venables (2001)).

[23]I discuss how I model these costs in more detail in the appendix.

protected by a policy barrier τ_{ij} that can vary across importers. Once goods cross this border, they arrive at the market and are consumed at a price inclusive of the factory gate price $p_{jj}(\omega)$ and these transportation and policy costs. Substituting Equation 14 into the gravity equation 12 gives

$$\lambda_{ij} = \frac{T_j \left(\rho_j \delta_{ij}(\boldsymbol{Z}_{ij}) \tau_{ij} w_j^{1-\beta} P_j^{\beta} \right)^{-\theta}}{\Phi_i}$$

The problem with taking this equation straight to the data is that it contains unobserved technologies and wages. This would also require taking a stance on several structural parameters. Comparing j's import penetration in i to its share of the home market λ_{jj} solves this problem, however. To see this, note

$$\frac{\lambda_{ij}}{\lambda_{jj}} = \left(\delta_{ij}(\boldsymbol{Z}_{ij}) \tau_{ij} \right)^{-\theta} \frac{\Phi_j}{\Phi_i}$$

Rearranging and substituting from Equation 13 gives the familiar relationship in Equation 1 discussed above, modified to separate trade barriers from freight costs.[24]

$$\tau_{ij} = \left(\frac{\lambda_{ij}}{\lambda_{jj}} \right)^{-\frac{1}{\theta}} \frac{P_i}{P_j} \frac{1}{\delta_{ij}(\boldsymbol{Z}_{ij})} \tag{15}$$

If the trade elasticity is known, data on trade shares, relative prices, and freight costs are sufficient to calculate policy barriers to trade, τ_{ij}. In the next section, I discuss how these data are constructed to match the model presented here.

Calibration

I present results from a calibration on a set of 24 of the world's largest economies in 2011.[25] These in-sample countries collectively made up 87 percent of world GDP. I treat the rest of the world as an aggregate outside economy. The calibration requires me to take a stance on two structural parameters, the Frechet parameter θ and the consumers' elasticity of substitution σ. I set $\sigma - 1 = \theta = 5$, in line with the estimates from the structural gravity literature (Head and Mayer 2014).

[24]Note that given prices, freight costs, and λ_{jj}, trade flows are a "sufficient statistic" for the magnitude of policy barriers to trade. In the face of opaque policy instruments, this provides a rationale for simply demanding trade deficit reductions in trade negotiations, a tactic utilized by the Trump administration in negotiations with China. Wei, Lingling. "U.S. and China Make Scant Progress in Trade Talks." *The Wall Street Journal*. 4 May, 2018.

[25]The list of the economies in the sample is included in the Appendix.

Prices and Consumer Expenditures

In order to calculate policy barriers to trade, I require an empirical analogue of the Equation 4, the country-specific price index. This quantity summarizes the overall level of competition in the economy, summarized in the market price of tradable varieties. Data on cross-national prices comes from the World Bank's International Comparison Program, used to calculate Purchasing Power Parities (PPP).[26]

The ICP surveys prices of hundreds of products and services across 146 countries, and chooses product lists to maximize comparability across markets. They also report the share of GDP that is allocated toward puchases of different product categories, termed "basic headings." After using the prevailing exchange rate to convert prices into U.S. dollars, various (largely atheoretical) statistical methods are used to compute internationally comparable price indices across basic headings.[27] I classify each basic heading as tradable or nontradable and report the results of this classification in the Appendix.[28]

I take these basic headings as the empirical analogue to good categories k in the model. I assume that the local price of each variety in category k is constant, $p_i(\omega) = p_i(\omega') = p_{ik}$ for all $\omega, \omega' \in \Omega_k$. Then, the price index in Equation 4 can be written

$$P_i = \left(\int_{\omega} \alpha_{h(\omega)} p_i(\omega)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} = \frac{1}{K} \left(\sum_k \alpha_k p_{ik}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

If the elasticity of substitution and the vector $\boldsymbol{\alpha} = \{\alpha_0, ..., \alpha_{K-1}\}$ are known, then price indices can be calculated from the ICP's price data, $\boldsymbol{p}_i = \{p_{i0}, ..., p_{i,K-1}\}$ and data on consumer expenditures. In the Appendix, I show how calculate an estimate for consumer tastes, $\hat{\boldsymbol{\alpha}}$ and employ this estimate to calculate empirical price indices. Because preferences do not vary by country, this amounts to minimizing the distance between observed and predicted product-level expenditures across countries.

I plot the distribution of price indices and tradable expenditure shares on tradables that emerge from this procedure against per capita GDPs in Figure 3. Within my sample, consumers in wealthier countries tend to face higher prices. The total share of consumer expenditure on tradable goods ($\sum_{k=0}^{K-1} x_{ik}$) is the empirical analogue to ν_i. On average, consumers spend 38 percent of their income on tradable goods.

[26] Rao (2013) details the underlying data and methodology. Deaton and Heston (2010) discusses challenges in working with these data.

[27] See S. J. Redding and Weinstein (2018) for a discussion of the conditions under which these price indices correspond to their theoretical counterparts.

[28] Simonovska and Waugh (2014) undertake the same exercise. My classification differs slightly from theirs.

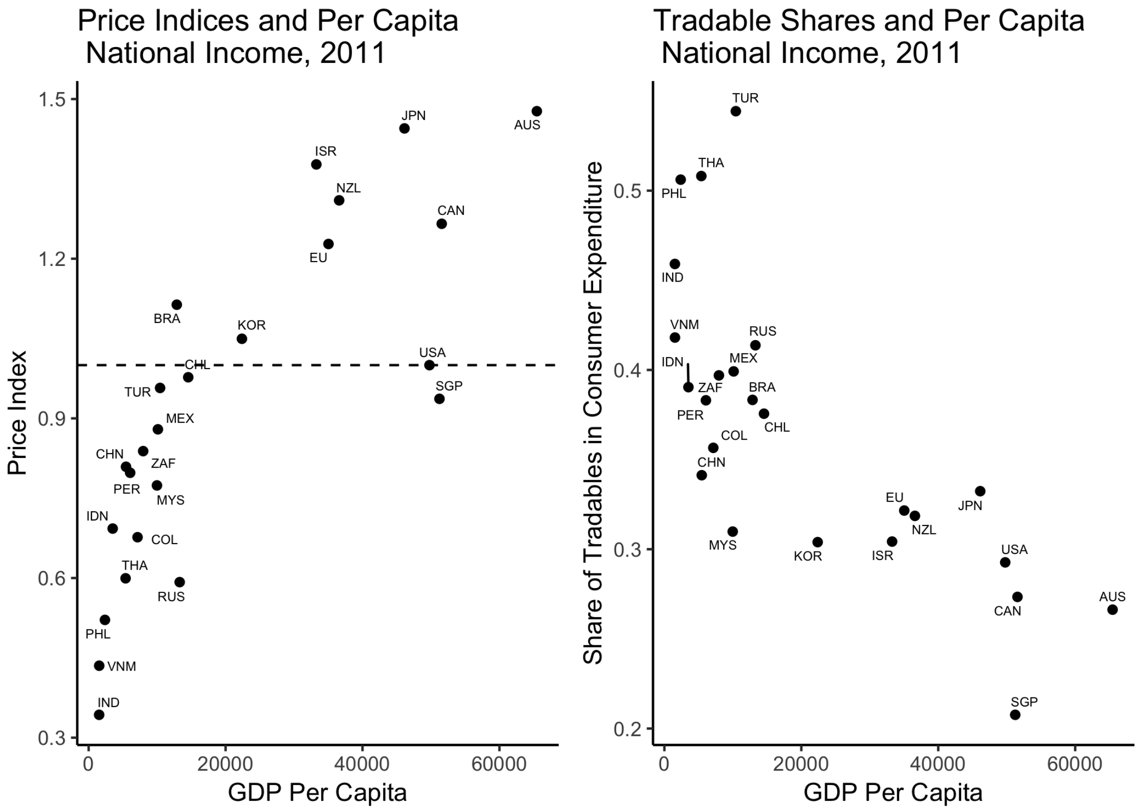

Figure 3: Price indices and tradable expenditure shares

Expenditure Shares

The theory makes predictions about the share of consumer expenditure that will be devoted to products from each country. In the data, however, I only observe the value of imports *at the border*. Price distortions due to policy barriers to trade are not included in the valuations of shipments. Let $\lambda_{ij}^{\text{cif}}$ denote the share of i's expenditure on tradables spent on goods from j, inclusive of freight rates and exclusive of policy barriers. We can then write $\lambda_{ij} = \tau_{ij}\lambda_{ij}^{\text{cif}}$.[29] Substituting this relationship into 15 gives a modified equation relating observed trade flows, prices, and freight rates to unobserved policy barriers to trade

$$\tau_{ij} = \left(\frac{\lambda_{ij}^{\text{cif}}}{\lambda_{jj}}\right)^{-\frac{1}{\theta+1}} \left(\frac{P_i}{P_j}\right)^{\frac{\theta}{\theta+1}} \left(\frac{1}{\delta_{ij}(\boldsymbol{Z}_{ij})}\right)^{\frac{\theta}{\theta+1}} \tag{16}$$

Then, to calculate $\lambda_{ij}^{\text{cif}}$ and λ_{jj}, I need data on international trade flows as well as the market share of domestic tradables producers in their home market. Data on trade flows

[29]While tariffs are usually assessed on the f.o.b. value of shipments, non-tariff barriers cannot be tailored in this manner. For this reason, I assume the costs of policy barriers are assessed on shipments' c.i.f. values.

comes from the United Nations' COMTRADE, cleaned and harmonized by CEPII's BACI. BACI denominates trade flows in f.o.b. value, so predicted c.i.f. values can be calculated simply by multiplying these flows by δ_{ij}, estimated below. Total domestic consumption on tradables can then be inferred from national accounts data, which report gross output, gross consumption, and GDP.[30] I simply subtract the share of consumer expenditure on services implied by the ICP data from each country's gross consumption, which provides a measure of gross consumption on tradables, the empirical analogue to $E_i = \nu_i I_i$. These national accounts data are taken from the World Input Output Database (WIOD) and the OECD's National Input Output Tables. The share of domestic tradables producers of their home market is

$$\lambda_{jj} = \left(1 - \sum_{i \neq j} \lambda_{ji}^{\text{cif}} \right)$$

or total expenditures minus imports.

Freight Costs

I combine a variety of data sources on factual freight costs and modes of transportation with bilateral geographic covariates to estimate aggregate freight costs between all countries in my sample. These predicted values serve as the δ_{ij} in Equation 15.[31] As depicted in Figure 5, all freight costs I observe cover the cost of shipments from border-to-border. They do not include costs that are incurred during intranational transit (ρ_i), which are differenced out of Equation 15. I discuss these data sources and the methodology used to estimate freight costs in the Appendix. Predicted freight costs average 6 percent the value of shipments and are positively correlated with distance.

Figure 4 depicts factual and predicted freight costs for the United States, Australia, New Zealand, and Chile in 2011. The observations for New Zealand and Chile are out of sample – the model was not trained on these data.[32] The out of sample fit is reasonable. Chile and New Zealand's predicted bilateral freight costs have a mean absolute error of 2 percentage points.

[30] Gross consumption includes consumer final expenditure as well as producers' expenditure on intermediates and is inclusive of trade deficits.

[31] Because the bilateral covariates used are symmetric between any two countries, predicted freight costs are nearly symmetric as well ($\delta_{ij} \approx \delta_{ji}$). Differences in the product-level makeup of trade are the only asymmetry introduced in my framework. Takahashi (2011) and Behrens and Picard (2011) show scale economies in shipping generally do produce asymmetries in bilateral freight costs. However, given the small ratio of freight costs to implied policy barriers, accounting for these asymmetries are unlikely to fundamentally alter my results.

[32] The model of aggregate freight costs relies on information on transportation mode shares, which were not available for these countries. They do report c.i.f.-f.o.b. ratios, however.

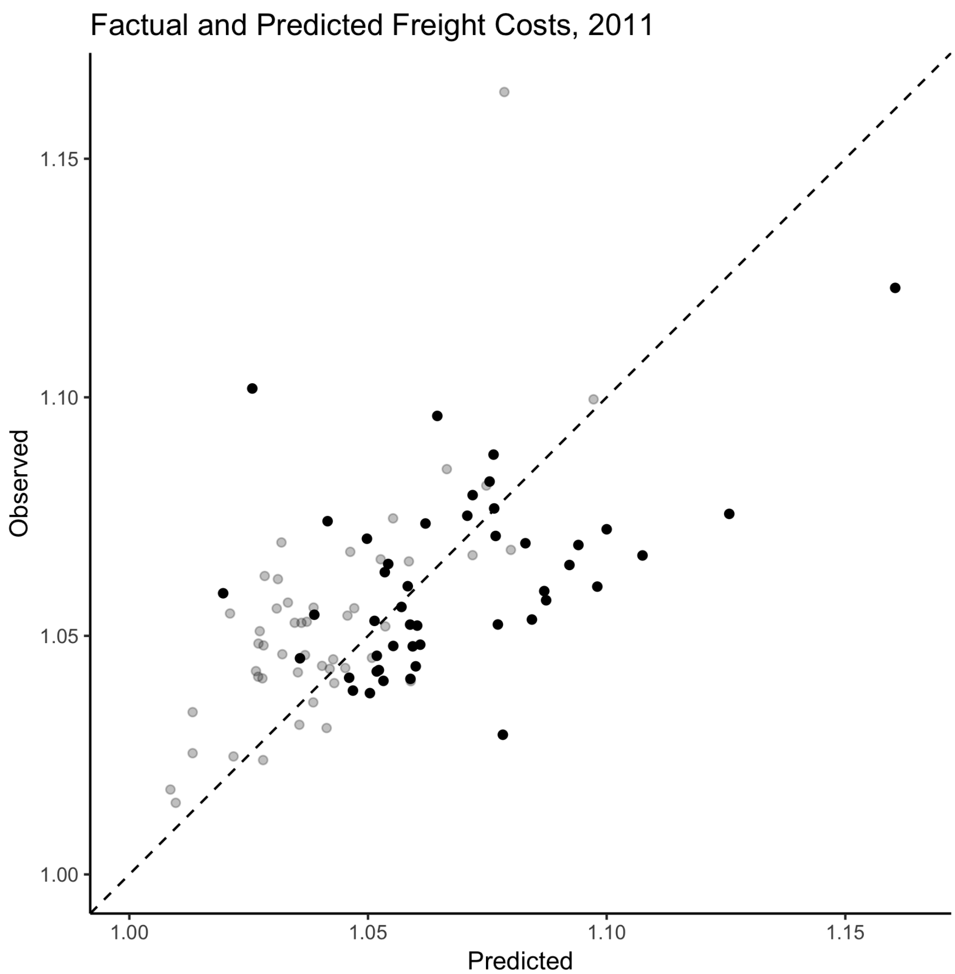

Figure 4: Factual versus predicted freight costs. In-sample observations are shown in grey. Out-of-sample observations are shown in black.

Results

The results of this exercise reveal substantial unobserved policy barriers to trade. In 2011, across all in-sample markets, exporters faced an average τ of 3.01, equivalent to a 201 percent import tariff.[33] The magnitude of these barriers dwarfs that of applied aggregate tariffs, which average only 4 percent within my sample. This result is consistent with J. E. Anderson and Van Wincoop (2003), Bradford (2003), De Sousa, Mayer, and Zignago (2012), and Waugh and Ravikumar (2016) which also uncover large implied trade costs using indirect measurement methods. Figure 5 shows the distribution of implied policy barriers (panel A), relative to tariffs and predicted freight costs.

[33] Of course, this result is sensitive to my stance on the trade elasticity. Doubling the trade elasticity to 9 cuts the average τ in half to 1.88

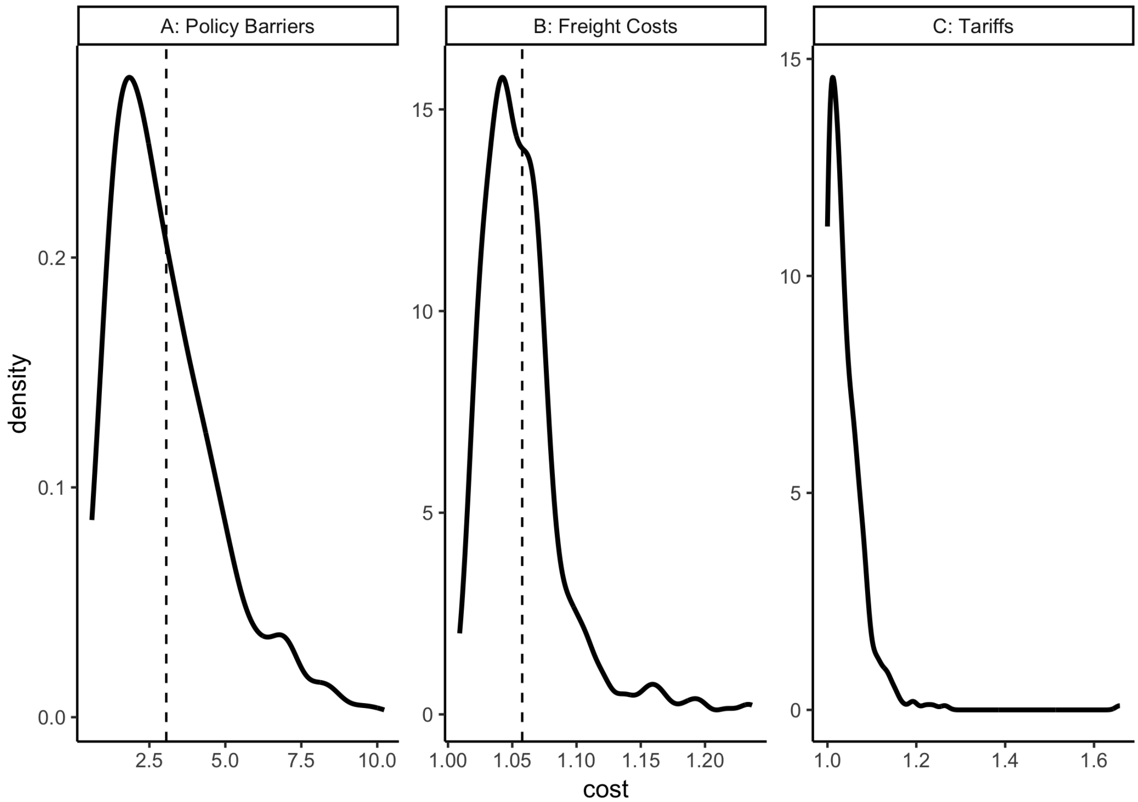

Figure 5: Distribution of freight costs, tariff barriers, and structural policy barriers to trade (τ_{ij}). Dashed lines show mean of each distribution.

The model and data jointly suggest that international trade remains far from free, even taking into account unavoidable freight costs. Returning to Equation 15, this result suggests that the observed international price gaps and trade flows are inconsistent with a trade barrier-less world, given predicted freight costs. The model suggests that if implied policy barriers were removed, some combination of increases in trade flows and the reduction of price gaps would occur.

International trade is also far from fair. A fair international trading system might allow for trade restrictions, but require that these restrictions affect all trading partners equally. In fact, policy barriers to trade are quite discriminatory. In 2011, the mean within-country standard deviation of τ_{ij} is 1.36, representing a significant preferential margin for preferred trade partners. For example, in 2011, U.S. trade with Canada ($\tau_{ij} = 1.49$), Japan (1.59), and the European Union (1.53) was relatively unhindered. Conversely, U.S. trade with Peru (4.13) and Vietnam (5.27) was highly restricted.

Figure 6 shows the distribution of directed policy barriers to trade in the data. The latent trade discrimination implemented by the United States is not unique – openness varies significantly at the importer-exporter level. Figure 6 also reports the magnitude

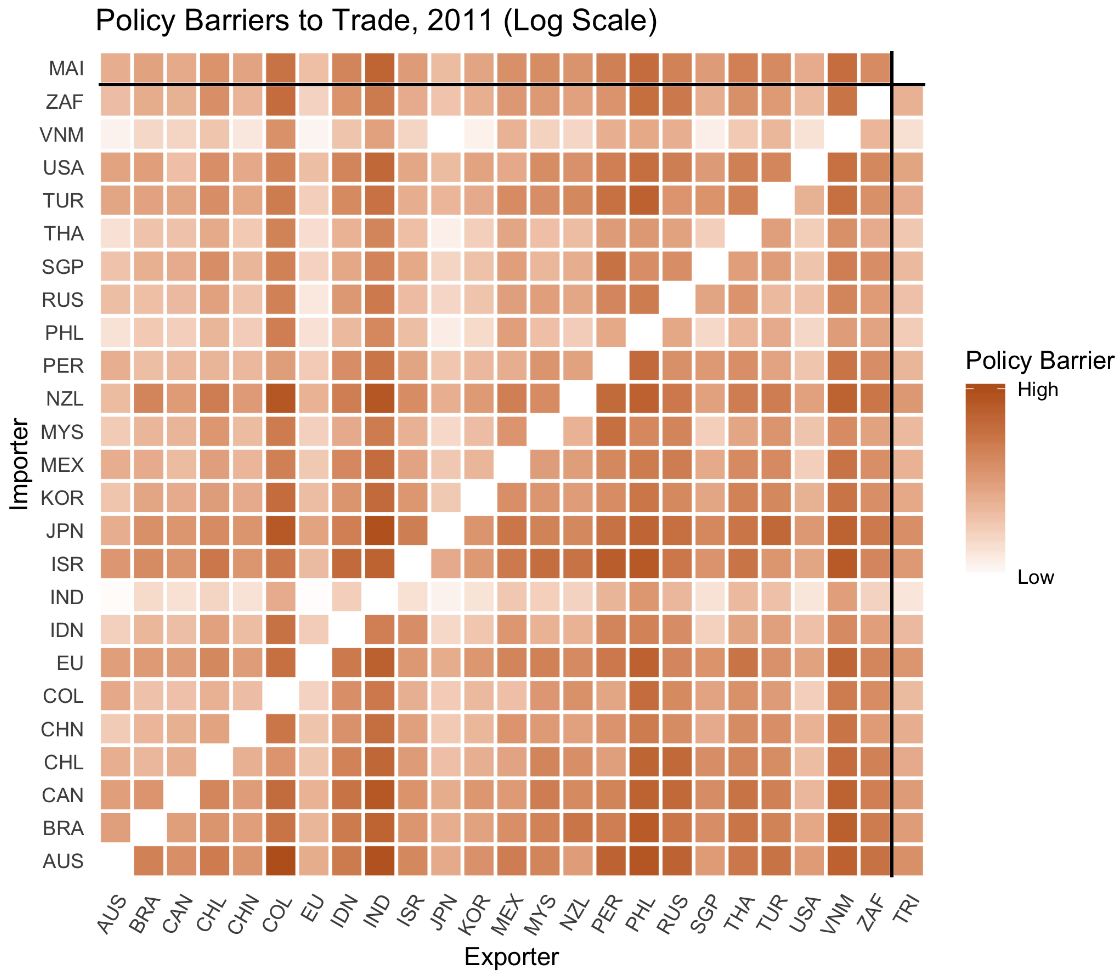

Figure 6: Distribution of policy barriers to trade. Each cell reports the magnitude of the policy barrier each importing country (y-axis) imposes on every exporting country (x-axis). In the margins are the magnitudes of each country's Trade Restrictivenss Index (TRI) and Market Access Index (MAI), defined in Equations 17 and 18, respectively.

of two indices – a Trade Restrictiveness Index (TRI) and a Market Access Index (MAI) – that summarize each country's import restrictiveness and international market access conditions, respectively. The TRI is simply a weighted average of the policy barriers an importing country imposes on all other countries, where the weights are the gross tradable expenditures of these other countries.[34]

[34] I use gross consumption, rather than observed flows, as weights for consistency with the theoretical framework. Trade flows are endogenous to each country's trade policy decisions. In a friction-less world, exporters would capture a constant share of every market's gross expenditure on tradables.

$$\mathrm{TRI}_i = \frac{1}{\sum_{j \neq i} E_j} \sum_{j \neq i} \tau_{ij} E_j \tag{17}$$

Similarly, the market access index is an expenditure weighted average of the barriers that all importing countries impose on the exports of a given country.

$$\mathrm{MAI}_j = \frac{1}{\sum_{i \neq j} E_i} \sum_{i \neq j} \tau_{ij} E_i \tag{18}$$

Higher values of the TRI correspond to higher aggregate trade restrictiveness. Conversely, higher values of the MAI correspond to lower aggregate market access (a high tax on a country's exports).

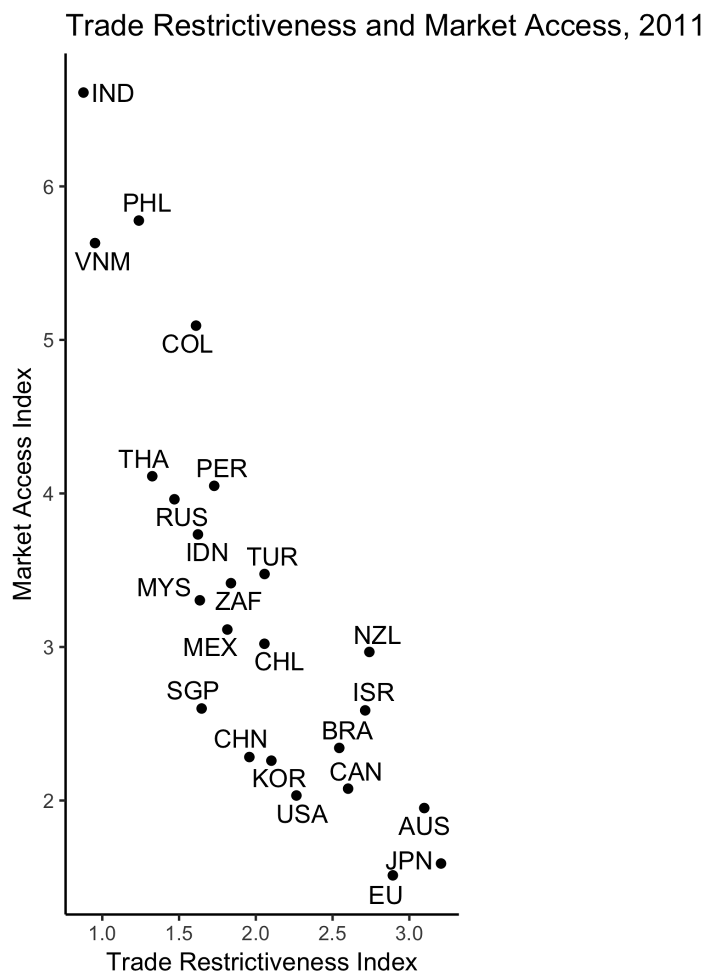

Figure 7: Trade restrictiveness and market access conditions by country

Figure 7 plots the TRIs and MAIs jointly. A negative correlation between these indices emerges naturally from the structure of the model. High domestic prices imply arbitrage opportunities, raising the TRI. They also imply high opportunity costs for domestic exporting firms that forgo these high prices. To rationalize these flows, the model infers that these firms must face relatively friendly market access conditions abroad, raising the MAI.

Correlates of Unobserved Policy Barriers to Trade

Figure 5 shows that tariffs cannot account for the magnitude of trade protection implied by the model. What, then, is the source of these policy distortions? As discussed in the introduction, governments have a dizzying slate of policy instruments at their disposal which can have direct or indirect effects on trade. Existing studies of trade protection generally leverage these observable proxies of the broader, unobservable, aggregate policy barrier that is the target of this study (Kee, Nicita, and Olarreaga 2009).

Such observable proxies include tariffs, but also NTMs and preferential trade agreements (PTAs). NTMs are simply regulations that affect what kinds of products can and cannot be imported. Some NTMs, such as quotas, are rather blunt in their impact, while others, such as health and safety regulations, are more subtle. PTAs usually lower tariff rates beyond WTO commitments within a bloc of signatory countries. Increasingly, these agreements also work to harmonize regulatory environments and reduce "behind-the-border" barriers to trade (Baccini 2019). If in fact NTMs impede trade and PTAs facilitate trade, they should be correlated with the aggregate policy barriers to trade captured here.

To evaluate this proposition, I gather data on applied tariff rates, NTMs, and PTAs, and run a simple regression to evaluate the correlation between these observable indicators of trade restrictiveness and my metric.

I measure aggregate tariff protection with a trade-weighted average of applied tariff rates, taken from UN Conference on Trade and Development's (UNCTAD) TRAINS database.[35] UNCTAD also tracks the incidence of NTMs in governments official trade regulations. As is standard in the literature on NTMs,[36] I employ NTM coverage ratios as a measure of aggregate NTM protection. A coverage ratio is simply the proportion of Harmonized System (HS) 6-digit tariff lines that are subject to an NTM. I group NTMs into three categories, price/quota (core), health/safety, and other, and calculate coverage ratios for each category.[37] Finally, I construct a binary indicator that takes the value of one if two countries are members of a bilateral or multilateral PTA, and zero if not, employing the DESTA database (Dür, Baccini, and Elsig 2014). I include importer and exporter fixed

[35] This allows the measure to vary at the trade partner level, as exporters with different product portfolios are differentially exposed to tariff lines.

[36] See, for example, J. E. Anderson and Van Wincoop (2004).

[37] Due to data availability constraints, data for the European Union is taken from 2012, while the rest of the NTM data is taken from 2011. NTM data for South Korea is unavailable, so it is dropped from the analysis.

effects in order to make comparisons relative to mean levels of protection and market access.

Table 1: Correlates of Structural Policy Barriers, 2011

	Dependent variable:
	Structural Policy Barrier
Tariffs	1.791^{**}
	(0.887)
PTAs	-0.517^{***}
	(0.093)
Core NTM	0.181
	(0.249)
Health/Safety NTM	0.368
	(0.229)
Other NTM	-0.465
	(0.311)
Importer Fixed Effects	✓
Exporter Fixed Effects	✓
Observations	440
R^2	0.858
Note:	*p<0.1; **p<0.05; ***p<0.01

The results are shown in Table 1. Estimated policy barriers are positively correlated with observed tariffs. Independently of tariff rate reductions, policy barriers are negatively correlated with the existence of a PTA. This is consistent with PTAs as a tool of "deep liberalization" that reduce trade costs in excess of those imposed by tariffs. In particular, the existence of a PTA is associated with a tariff-equivalent decrease in τ_{ij} of 52 percentage points. Policy barriers show no significant association with any category of NTMs. However, coverage ratios are an extremely coarse measure of the magnitude of NTMs, and the TRAINS data are of imperfect quality (Kono 2008).

A Placebo Test: Intra-European Union Barriers

In the preceding analysis, the European Union (EU) member states were treated as a single economic entity. Within the EU, goods face few policy barriers to trade. The EU customs union eliminates direct barriers to trade assessed at the border, and regulatory harmonization efforts seek to minimize indirect barriers. For this reason, intra-EU policy barriers to trade should be substantially lower than external barriers. Because the EU documents internal trade and the ICP collects price data for each EU member state, I can test this hypothesis in the data. To do so, I first employ my freight cost model to predict shipping costs within EU member states. European Union policy barriers to trade can then be disaggregated by member state.[38]

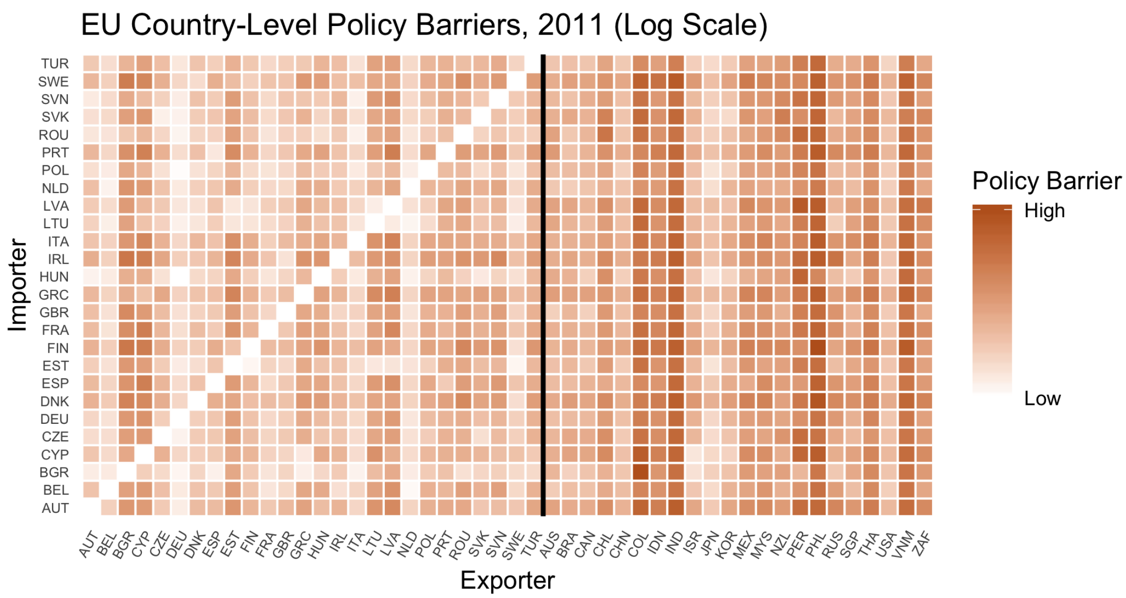

Figure 8: Intra and extra-European Union policy barriers to trade. Each cell reports the magnitude of the policy barrier each EU importing country (y-axis) imposes on every exporting country (x-axis). Barriers toward EU countries are on the left hand side of the solid line. Barriers toward non-EU countries are on the right hand side of the solid line.

Figure 8 depicts the results of this exercise. EU policy barriers toward other EU member

[38]There were 27 members of the European Union in 2011, and Turkey participated in the economic bloc through a customs union. Due to inconsistencies between its trade and national accounts data, I drop Malta from the analysis.

states are on average 51 percent the size of barriers with non-EU states.[39] Barriers are far from nonexistent, however. On average, EU countries implement an tariff-equivalent barrier of 98 percent on other EU member states, compared to 189 percent on non-EU states.[40] From the perspective of the model, there remained substantial policy-related trade frictions within the EU in 2011. This finding is consistent with the existence of "border effects" within the EU (Comerford and Mora 2015). Of course, these inferences might be driven by features of the model itself. I discuss these limitations in more detail in the paper's conclusion.

Discussion

In the introduction, I noted that richer countries tend to have higher policy barriers to trade, contrary to their relatively liberal tariff regimes. From this fact, some conclude that political institutions in developed countries are more "welfare-concious" than those in their developing counterparts (Gawande, Krishna, and Olarreaga 2009; Gawande, Krishna, and Olarreaga 2015). These results are consistent with an alternative approach, emphasizing state capacity, articulated in Acemoglu (2005), Rodrik (2008), and Queralt (2015). Here, tariffs emerge as a "second-best" solution to a revenue-raising problem facing low-capacity governments, which struggle to raise revenue through other channels. As capacity grows, governments employ alternative instruments to raise revenues. As shown here, these governments do not necessarily become less protectionist in the process. In fact, they may become more closed to international trade.

Due to the restrictiveness and discrimination inherent in developed countries' trade policies, poor countries also struggle to access international markets, shown in Figure 9. Several studies examining trade costs as a whole replicate this finding, and suggest that this explains some of the variation in cross-national income per capita (S. Redding and Venables 2004; Romalis 2007; Waugh 2010). These results suggest that even complete tariff liberalization on the part of developed countries would still leave developing countries confronting substantial market access barriers.

Conclusion

The structure of global tariff rates suggests that international trade is relatively free and fair. Does this conclusion extend to non-tariff barriers to trade? I have shown that the policy barriers to trade implied by observed prices, trade flows, and freight costs are

[39] This comparison was made by taking weighted means of tariff-equivalent policy barriers where the weights are the expenditures on tradable goods of the exporting countries.

[40] These are unweighted averages of EU member states' TRIs, calculated with respect to EU and non-EU members respectively.

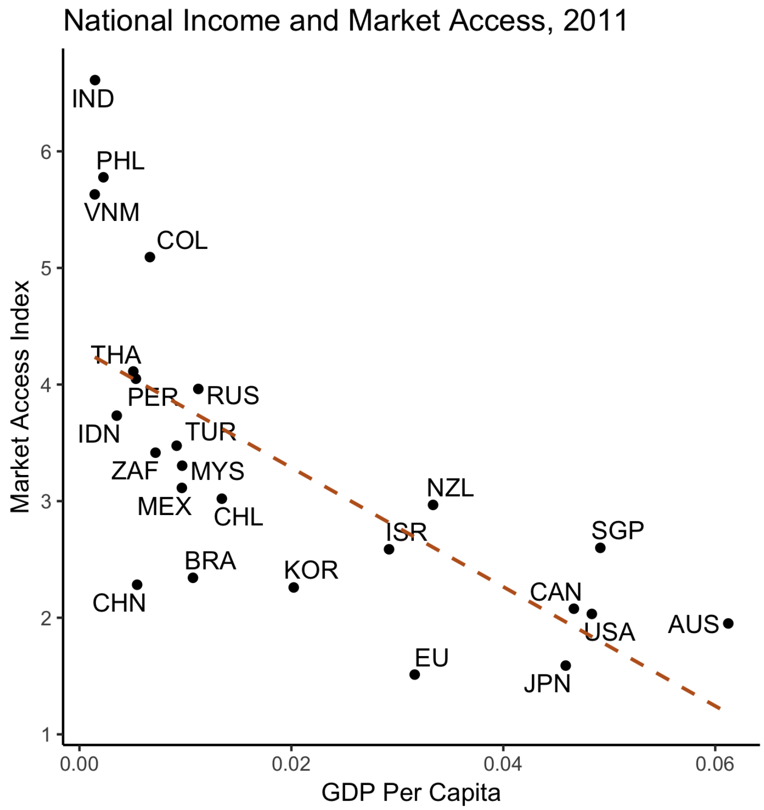

Figure 9: Market access conditions and per capita national income

quite large and are implemented in a discriminatory manner. In particular, developed countries implement high non-tariff barriers to trade and tend to discriminate against their less-developed trading partners.

I should qualify these conclusions on three counts. First, like most studies of international trade, they are model-dependent. My approach accounts for trade in intermediate inputs, but does so rather bluntly. Global value chains are complex and respond non-linearly to changes in trade costs (Yi 2003), a feature not captured here. The nested CES preferences ascribed to consumers are also rather rigid. This inflexibility may affect the proportion of distortions attributed to trade costs, rather than consumer heterogeneity, a point noted by Waugh (2010). Second, my conclusions depend on the accuracy of the ICP's price data, and on the assumption that producers face the same prices as consumers. If the price level in Japan is factually less than twice that of Malaysia, Japan's implied policy barriers to trade will also fall. Similarly, if intermediate input prices differ systematically from the prices of final goods, this will change my conclusions on the magnitude of policy barriers to trade. Finally, the simple calibration exercise conducted here cannot speak to uncertainty about the magnitude of policy barriers to trade. From the perspective of Equation 15, measurement error in prices and trade flows and estimation error in the trade elasticity and predicted trade costs will aggregate to produce a window of uncertainty the true value of τ_{ij}. Some combination of better theory and better data will strengthen the precision of the conclusions made here.

Appendix

Empirical Price Index: Estimating CES Taste Parameters

Demand for variety ω is

$$q_i(\omega) = \alpha_{h(\omega)} p_i(\omega)^{-\sigma} E_i^q P_i^{\sigma-1}$$

and expenditure is

$$x_i(\omega) = p_i(\omega) q_i(\omega) = \alpha_{h(\omega)} p_i(\omega)^{1-\sigma} E_i^q P_i^{\sigma-1}$$

With constant prices in each basic heading, total spending on goods in category k is

$$\begin{aligned}
x_{ik} &= \int_{\omega \in \Omega_k} \alpha_{h(\omega)} p_i(\omega)^{1-\sigma} E_i^q P_i^{\sigma-1} d\omega \\
&= \int_{\omega \in \Omega_k} \alpha_k p_{ik}^{1-\sigma} E_i^q P_i^{\sigma-1} d\omega \\
&= \frac{1}{K} \alpha_k p_{ik}^{1-\sigma} E_i^q P_i^{\sigma-1}
\end{aligned}$$

The share of i's tradables expenditure spent on goods in category k is

$$\lambda_{ik} = \frac{x_{ik}}{E_i^q} = \frac{1}{K} \alpha_k p_{ik}^{1-\sigma} P_i^{\sigma-1}$$

Normalizing $\alpha_0 = 1$ gives

$$\frac{\lambda_{ik}}{\lambda_{i0}} = \alpha_k \left(\frac{p_{ik}}{p_{i0}} \right)^{1-\sigma}$$

Consumers are subject to relative demand shocks ϵ_{ik} that are i.i.d. across countries and good categories. Observed relative expenditure is then

$$\begin{aligned}
\frac{\lambda_{ik}}{\lambda_{i0}} &= \alpha_k \epsilon_{ik} \left(\frac{p_{ik}}{p_{i0}} \right)^{1-\sigma} \\
\Delta\lambda_{ik} &= \alpha_k \epsilon_{ik} \left(\Delta p_{ik} \right)^{1-\sigma}
\end{aligned}$$

Taking logs,

$$\ln \Delta\lambda_{ik} = \ln \alpha_k + (1-\sigma) \ln \Delta p_{ik} + \ln \epsilon_{ik}$$

Rearranging

$$\ln \epsilon_{ik} = \ln \Delta\lambda_{ik} - (1-\sigma)\ln \Delta p_{ik} - \ln \alpha_k$$
$$= \varphi_{ik} - \gamma_k$$

where

$$\varphi_{ik} = \ln \Delta\lambda_{ik} - (1-\sigma)\ln \Delta p_{ik}$$

and $\gamma_k = \ln \alpha_k$.

Let $\ln \epsilon_{ik} \sim \mathcal{N}(0, \sigma_\epsilon^2)$. Then, a weighted least squares estimate for $\ln \alpha_k$ solves

$$\hat{\gamma}_k = \arg\min_{\gamma_k} \sum_i w_i \epsilon_{ik}^2 = \sum_i w_i \left(\varphi_{ik} - \gamma_k\right)^2$$

with $\sum_i w_i = 1$ and is given by

$$\hat{\gamma}_k = \sum_i w_i \varphi_{ik}$$

I use as weights each country's total expenditure on tradeables, E_i^q. The theory-consistent estimate for the price index can then be calculated as

$$\hat{P}_i = \left(\int_\omega \hat{\alpha}_{h(\omega)} p_i(\omega)^{1-\sigma}\right)^{\frac{1}{1-\sigma}} = \frac{1}{K}\left(\sum_k \hat{\alpha}_k p_{ik}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

Modeling Freight Costs and Data Sources

In order to estimate the magnitude of policy barriers to trade, I must difference out the component of trade costs attributable to freight costs. However, freight costs are, at best, *partially* observed. I employ data from the United States Census Bureau and the Australian Bureau of Statistics on the c.i.f. and f.o.b. values of its imports.[41] The ratio of the c.i.f. value of goods to their f.o.b. value can then be taken as a measure of the ad valorem freight cost. I supplement these values with international data on the costs of *maritime* shipments from the OECD's Maritime Transport Cost Dataset (Korinek 2011). I also observe the transportation modes of imports (air, land, or sea) to the European Union, Japan, Brazil, Australia and the United States .[42]

Geographic covariates $\boldsymbol{Z}_{ij}$ include indicators of air and sea distances between i and j, whether or not i and j are contiguous, and whether or not i and/or j are island countries.

[41] The Australian data are also used by Shapiro (2016) and Adao, Costinot, and Donaldson (2017).

[42] Data from the United States come from the Census Bureau and are available on the website of Peter Schott. Data from the European Union are from Eurostat. Data from Japan are from the government's statistical agency, e-Stat. Data from Brazil come from the ministry of trade and industry. Data from Australia are from the Australian Bureau of Statistics.

Sea distances are from CERDI (Bertoli, Goujon, and Santoni 2016). The remainder of these data are from CEPII's GeoDist database (Mayer and Zignago 2011).

To model international freight costs, assume there are M categories of goods, indexed $m \in \{1, ..., M\}$ and K modes of transportation, indexed $k \in \{1, ..., K\}$.

The total free on board (f.o.b.) value of imports of country i from country j is given by X_{ij}. The cost, insurance, and freight (c.i.f.) value of these goods is $\delta_{ij} X_{ij}$. These c.i.f. costs can be decomposed by product and mode of transporatation as follows

$$\delta_{ij} X_{ij} = \sum_{m=1}^{M} \delta_{ij}^{m} x_{ij}^{m}$$

where

$$\delta_{ij}^{m} x_{ij}^{m} = \sum_{k=1}^{K} \delta_{ij}^{mk} x_{ij}^{mk} \implies \delta_{ij}^{m} = \sum_{k=1}^{K} \delta_{ij}^{mk} \frac{x_{ij}^{mk}}{x_{ij}^{m}}$$

Let ζ_{ij}^{mk} denote the share of imports by i from j of good m that travel by mode k

$$\zeta_{ij}^{mk} = \frac{x_{ij}^{mk}}{x_{ij}^{m}}$$

In the data, I observe product-level trade flows, x_{ij}^{m}, but observe only a subset of ad valorem freight costs by mode δ_{ij}^{mk} and mode shares ζ_{ij}^{mk}.[43] I also observe bilateral geographic covariates $\boldsymbol{Z}_{ij}$ and product dummies $d^m \in \{0, 1\}$ that may be predictive of freight costs and mode shares. To compute aggregate freight costs δ_{ij} for all country pairs in our sample, I seek functions

$$g : \{\boldsymbol{Z}_{ij}, d^m\} \to \delta_{ij}^{mk}$$
$$h : \{\boldsymbol{Z}_{ij}, d^m\} \to \zeta_{ij}^{mk}$$

from which I can compute

$$\hat{\delta}_{ij} \left(\boldsymbol{Z}_{ij}, \boldsymbol{d}_{ij} \right) = \frac{1}{X_{ij}} \sum_{m=1}^{M} x_{ij}^{m} \sum_{k=1}^{K} g \left(\boldsymbol{Z}_{ij}, d^m \right) h \left(\boldsymbol{Z}_{ij}, d^m \right)$$

Let $\tilde{\boldsymbol{\delta}}$ and $\tilde{\boldsymbol{\zeta}}$ denote sets of observed freight costs and mode shares. Let $\mathcal{G}$ denote the set of possible functions g and $\mathcal{H}$ denote the set of possible functions h. I choose g and h to satisfy the following

[43] All these variables are aggregated at the HS-2 level.

$$
\begin{aligned}
\hat{g}^m = \min_{g \in \mathcal{G}} \quad & \sum_{\delta_{ij}^{mk} \in \tilde{\boldsymbol{\delta}}} \left(\delta_{ij}^{mk} - g\left(\boldsymbol{Z}_{ij}, d^m\right)\right)^2 \\
\text{subject to} \quad & g\left(\boldsymbol{Z}_{ij}, d^m\right) \geq 1
\end{aligned} \tag{19}
$$

$$
\begin{aligned}
\hat{h} = \min_{h \in \mathcal{H}} \quad & \sum_{\zeta_{ij}^{mk} \in \tilde{\boldsymbol{\zeta}}} \left(\zeta_{ij}^{\ell k} - h\left(\boldsymbol{Z}_{ij}, d^m\right)\right)^2 \\
\text{subject to} \quad & \sum_{k=2}^{K} h\left(\boldsymbol{Z}_{ij}, d^m\right) = 1
\end{aligned} \tag{20}
$$

I let $\mathcal{G}$ be the set of linear functions with polynomial time splines and $\mathcal{H}$ be the set of multinomial link functions, following Shapiro (2016). I impose the constraints in Equation 19 ex post, replacing values violating the constraint with 1.

This results in three functions $\hat{g}^m$ for each transportation mode (air, land, sea) and one function $\hat{h}$ that outputs predicted mode shares. The data used to estimate these functions is discussed in more detail below.

Freight Cost Results

Maritime Freight Costs

Table 2: Maritime Cost Model

	Dependent variable:
	Freight Cost
CERDI seadist (log, std)	0.010***
	(0.0002)
Contiguity	0.007***
	(0.0003)
Product fixed effects?	✓
Cubic time spline?	✓
Observations	178,195
R^2	0.502
Note:	*p<0.1; **p<0.05; ***p<0.01

Land Freight Costs

Table 3: Land Cost Model

	Dependent variable:
	Freight Cost
CEPII distw (log, std)	0.004^{***}
	(0.0002)
Contiguity	-0.014^{***}
	(0.0004)
Product fixed effects?	✓
Cubic time spline?	✓
Observations	48,949
R^2	0.436
Note:	*p<0.1; **p<0.05; ***p<0.01

Air Freight Costs

Table 4: Air Cost Model

	Dependent variable:
	Freight Cost
CEPII distw (log, std)	0.028^{***}
	(0.001)
Contiguity	-0.029^{***}
	(0.001)
Product fixed effects?	✓
Cubic time spline?	✓
Observations	107,288
R^2	0.431
Note:	*p<0.1; **p<0.05; ***p<0.01

Transportation Mode Shares

Table 5: Mode Share Model

	Dependent variable:		
	Air Share	Sea Share	Land Share
	(1)	(2)	(3)
Air Distance (log, std)	0.086^{***}	-1.599^{***}	-0.745^{***}
	(0.010)	(0.018)	(0.028)
Sea Distance (log, std)	-0.097^{***}	0.333^{***}	0.461^{***}
	(0.008)	(0.012)	(0.020)
Contiguity	-0.203^{***}	1.257^{***}	-1.671^{***}
	(0.051)	(0.047)	(0.251)
Importer Island?	-0.067^{***}	0.378^{***}	0.258^{***}
	(0.015)	(0.025)	(0.041)
Exporter Island?	-0.281^{***}	-4.736^{***}	-4.137^{***}
	(0.013)	(0.089)	(0.154)
Product fixed effects?	✓	✓	✓
Cubic time spline?	✓	✓	✓
Akaike Inf. Crit.	384,333.600	384,333.600	384,333.600
Note:			*p<0.1; **p<0.05; ***p<0.01

Sample Countries

iso3	Country Name
AUS	Australia
BRA	Brazil
CAN	Canada
CHL	Chile
CHN	China
COL	Colombia
EU	European Union
IDN	Indonesia
IND	India
ISR	Israel
JPN	Japan
KOR	Republic of Korea
MEX	Mexico
MYS	Malaysia
NZL	New Zealand
PER	Peru
PHL	Philippines
RUS	Russian Federation
SGP	Singapore
THA	Thailand
TUR	Turkey
USA	United States of America
VNM	Viet Nam
ZAF	South Africa

International Comparison Program Expenditure Categories

Code	Basic Heading	Tradable?
1101111	Rice	✓
1101112	Other cereals, flour and other products	✓
1101113	Bread	✓
1101114	Other bakery products	✓
1101115	Pasta products	✓
1101121	Beef and veal	✓
1101122	Pork	✓

(continued)

Code	Basic Heading	Tradable?
1101123	Lamb, mutton and goat	✓
1101124	Poultry	✓
1101125	Other meats and meat preparations	✓
1101131	Fresh, chilled or frozen fish and seafood	✓
1101132	Preserved or processed fish and seafood	✓
1101141	Fresh milk	✓
1101142	Preserved milk and other milk products	✓
1101143	Cheese	✓
1101144	Eggs and egg-based products	✓
1101151	Butter and margarine	✓
1101153	Other edible oils and fats	✓
1101161	Fresh or chilled fruit	✓
1101162	Frozen, preserved or processed fruit and fruit-based products	✓
1101171	Fresh or chilled vegetables other than potatoes	✓
1101172	Fresh or chilled potatoes	✓
1101173	Frozen, preserved or processed vegetables and vegetable-based products	✓
1101181	Sugar	✓
1101182	Jams, marmalades and honey	✓
1101183	Confectionery, chocolate and ice cream	✓
1101191	Food products nec	✓
1101211	Coffee, tea and cocoa	✓
1101221	Mineral waters, soft drinks, fruit and vegetable juices	✓
1102111	Spirits	✓
1102121	Wine	✓
1102131	Beer	✓
1102211	Tobacco	✓
1102311	Narcotics	
1103111	Clothing materials, other articles of clothing and clothing accessories	✓
1103121	Garments	✓
1103141	Cleaning, repair and hire of clothing	
1103211	Shoes and other footwear	✓
1103221	Repair and hire of footwear	
1104111	Actual and imputed rentals for housing	
1104311	Maintenance and repair of the dwelling	
1104411	Water supply	
1104421	Miscellaneous services relating to the dwelling	
1104511	Electricity	
1104521	Gas	✓
1104531	Other fuels	✓
1105111	Furniture and furnishings	✓
1105121	Carpets and other floor coverings	✓
1105131	Repair of furniture, furnishings and floor coverings	
1105211	Household textiles	✓
1105311	Major household appliances whether electric or not	✓
1105321	Small electric household appliances	✓
1105331	Repair of household appliances	
1105411	Glassware, tableware and household utensils	✓

(continued)

Code	Basic Heading	Tradable?
1105511	Major tools and equipment	✓
1105521	Small tools and miscellaneous accessories	✓
1105611	Non-durable household goods	✓
1105621	Domestic services	
1105622	Household services	
1106111	Pharmaceutical products	✓
1106121	Other medical products	✓
1106131	Therapeutic appliances and equipment	✓
1106211	Medical Services	
1106221	Dental services	
1106231	Paramedical services	
1106311	Hospital services	
1107111	Motor cars	✓
1107121	Motor cycles	✓
1107131	Bicycles	✓
1107141	Animal drawn vehicles	✓
1107221	Fuels and lubricants for personal transport equipment	✓
1107231	Maintenance and repair of personal transport equipemnt	
1107241	Other services in respect of personal transport equipment	
1107311	Passenger transport by railway	
1107321	Passenger transport by road	
1107331	Passenger transport by air	
1107341	Passenger transport by sea and inland waterway	
1107351	Combined passenger transport	
1107361	Other purchased transport services	
1108111	Postal services	
1108211	Telephone and telefax equipment	✓
1108311	Telephone and telefax services	
1109111	Audio-visual, photographic and information processing equipment	✓
1109141	Recording media	✓
1109151	Repair of audio-visual, photographic and information processing equipment	
1109211	Major durables for outdoor and indoor recreation	✓
1109231	Maintenance and repair of other major durables for recreation and culture	
1109311	Other recreational items and equipment	✓
1109331	Garden and pets	
1109351	Veterinary and other services for pets	
1109411	Recreational and sporting services	
1109421	Cultural services	
1109431	Games of chance	
1109511	Newspapers, books and stationery	✓
1109611	Package holidays	
1110111	Education	
1111111	Catering services	
1111211	Accommodation services	
1112111	Hairdressing salons and personal grooming establishments	
1112121	Appliances, articles and products for personal care	✓
1112211	Prostitution	

(continued)

Code	Basic Heading	Tradable?
1112311	Jewellery, clocks and watches	✓
1112321	Other personal effects	✓
1112411	Social protection	
1112511	Insurance	
1112611	Financial Intermediation Services Indirectly Measured (FISIM)	
1112621	Other financial services	
1112711	Other services nec	
1113111	Final consumption expenditure of resident households in the rest of the world	
1113112	Final consumption expenditure of non-resident households in the economic territory	
1201111	Individual consumption expenditure by NPISHs	
1301111	Housing	
1302111	Pharmaceutical products	✓
1302112	Other medical products	✓
1302113	Therapeutic appliances and equipment	✓
1302121	Out-patient medical services	
1302122	Out-patient dental services	
1302123	Out-patient paramedical services	
1302124	Hospital services	
1302211	Compensation of employees	
1302221	Intermediate consumption	
1302231	Gross operating surplus	
1302241	Net taxes on production	
1302251	Receipts from sales	
1303111	Recreation and culture	
1304111	Education benefits and reimbursements	
1304211	Compensation of employees	
1304221	Intermediate consumption	
1304231	Gross operating surplus	
1304241	Net taxes on production	
1304251	Receipt from sales	
1305111	Social protection	
1401111	Compensation of employees	
1401121	Intermediate consumption	
1401131	Gross operating surplus	
1401141	Net taxes on production	
1401151	Receipts from sales	
1501111	Fabricated metal products, except machinery and equipment	✓
1501121	General purpose machinery	✓
1501131	Special purpose machinery	✓
1501141	Electrical and optical equipment	✓
1501151	Other manufactured goods nec	✓
1501211	Motor vehicles, trailers and semi-trailers	✓
1501212	Other road transport	✓
1501221	Other transport equipment	✓
1502111	Residential buildings	
1502211	Non-residential buildings	
1502311	Civil engineering works	

(continued)

Code	Basic Heading	Tradable?
1503111	Other products	
1601111	Opening value of inventories	
1601112	Closing value of inventories	
1602111	Acquisitions of valuables	
1602112	Disposals of valuables	
1701111	Exports of goods and services	
1701112	Imports of goods and services	

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