Bilateral Trade, Relative Prices, and Trade Costs

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Abstract

Poor countries import a larger volume of goods from rich countries, than rich countries import from poor countries. Furthermore, there is little difference in comparable price indices for tradable goods between rich and poor countries. Standard empirical implementation of structural gravity models with distance and other symmetric relationships for trade costs cannot account for both of these facts. To account for these facts, I argue that trade costs must be systematically asymmetric with poor countries facing higher costs to export relative to rich countries. I then demonstrate that asymmetry is quantitatively important accounting for at least a third of the variation in bilateral trade—on par or more important than distance and other symmetric relationships. Given these observations, I propose a trade cost function and demonstrate how it can reconcile the discrepancy between the results of Eaton and Kortum (2001) and Hsieh and Klenow's (2007) observations regarding cross-country differences in the price of investment goods.

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1 Introduction

The most basic model of bilateral trade flows is the "Gravity Model" pioneered by Tinbergen (1962). Since then, there have been numerous derivations of the model and it is central to the empirical study of trade flows and related issues in international economics. They relate trade flows to country characteristics and trade costs. The relationship to Isaac Newton's famous law arises when size proxies the country characteristics and distance proxies the costs to trade. In structural gravity models, country characteristics are explicit functions of preferences, technologies, and endowments.

Gravity models are empirically successful. For example, using the model and data in this paper, estimating a structural gravity equation results in a high R-square and the effect of distance is both an economically and statistically significant impediment to trade. Furthermore, borders, trading blocs, monetary unions, etc., all are found to have statistically important effects on the volume of trade within gravity models. Success is often declared on the basis of these results.

Behind this success, empirical implementation of gravity models impose strong assumptions on the form of trade costs. For example, it is common to assume that trade costs are a function of distance, shared border, language, colonial relationship, etc. The common theme in these relationships is that they are *symmetric*. However, why should trade costs be symmetric? What are the implications of these assumptions? In this paper, I argue that these assumptions abstract from first-order features of the data in the context of a standard structural gravity model. I show that to account for bilateral trade volumes and relative price differences, costs to trade must be systematically asymmetric with poor countries facing higher costs to export relative to rich countries.

To study this pattern, I employ a simple multi-country general equilibrium model of trade along the lines of Eaton and Kortum (2002). This model provides a structural link between bilateral trade flows, each country's costs of production, and "iceberg" costs to trade.[1] Driving my results are two observations about the data and one from the model. First, data on bilateral trade volumes show that poor countries import a larger share of goods from rich countries, than rich countries import from poor countries — even after adjusting for each country's economic size. Second, comparable price indices for tradable goods are similar across rich and poor countries. Third, in the model relative size adjusted trade volumes are a monotonic function of relative prices and relative trade costs. Thus to explain differences in the size adjusted volume of trade between rich and poor countries and because relative price differences are small, trade costs must account for a majority of this difference and they must be systematically asymmetric with poor countries facing higher costs to export relative to rich countries.

Throughout the rest of the paper, I argue that this result is robust, that asymmetry is quantitatively important to understanding bilateral trade volumes, and I propose an approach to model this asymmetry. Regarding the quantitative importance of this result, the mere recognition of the pattern implies nothing about the behavior of the model with or without asymmetry. Thus I

[1] Though I work in the framework of Eaton and Kortum (2002), my arguments are applicable to the structural gravity model employed in Anderson and van Wincoop (2003), soon an appendix will be provided demonstrating this claim.

perform a quantitative exercise in the spirit of Chari, Kehoe, and McGrattan (2007) to assess the importance of asymmetry relative to alternative forces behind bilateral trade volumes. To differentiate among possibilities, I decompose trade costs in to identifiable asymmetric and symmetric components, measure each country's endowment, and recover a productivity residual such that the model exactly replicates bilateral trade volumes in equilibrium. Through counterfactual exercises, I study how much of the variation in bilateral trade volumes the model — with symmetric trade costs, asymmetric trade costs, and productivity differences separately and in combination — can replicate in equilibrium.

In this equilibrium decomposition exercise, asymmetric components, symmetric components, and productivity differences capture almost 75 percent of the variation in bilateral trade volumes with the rest attributed to noise. Of this 75 percent, each component contributes approximately one third of the variation. Quantitatively, the systematic asymmetry I identify is important to understanding bilateral trade volumes. The implication of this result is that since cross-country productivity differences and systematic asymmetry in trade costs do not have simple explanations (at least relative to distance) our understanding of bilateral trade volumes is quite limited, despite the perceived success of the gravity equation.

Given these observations, I propose an approach to model this asymmetry. The basic idea is to assume trade costs that are a function of symmetric relationships and an exporter fixed effect. Employing this rather simple approach significantly improves the fit of the model relative to a model only symmetric relationships. Comparing the coefficient estimates from my model relative to a model with only symmetric relationships, the results suggest the estimates are biased when some form of asymmetry is not incorporated into the model. And my trade cost function generates prices consistent with those in the data.

My approach relates to modeling trade costs relates to two prominent papers studying comparable price indices for investment goods: Eaton and Kortum (2001) and Hsieh and Klenow (2007). The work of Eaton and Kortum (2001, 2002) are exceptions to the gravity literature which allow for asymmetries by employing an importer fixed effect in their trade cost function. However, their approach delivers prices that systematically deviate from price data for poor countries. For example, Eaton and Kortum (2001) studied trade flows and comparable price indices for investment goods. They estimated a structural gravity equation for bilateral trade flows in investment goods and studied the model implied price indices. They find the estimated prices of investment goods are systematically higher for poor countries relative to rich countries, in contrast to the data with poor countries facing similar prices relative to rich countries.

Hsieh and Klenow (2007) criticize the results of Eaton and Kortum (2001) in their study of the data on investment prices and real investment rates without considering the implications of their arguments for reconciling trade flows. They argue that because poor countries face similar prices for investment goods relative to rich countries, lower real rates of investment for poor countries are not a result of distortions such as high tax rates and or trade frictions. Instead they argue poor countries must face difficulties in producing investment goods and exportables.

Between the results of Eaton and Kortum (2001) and Hsieh and Klenow's (2007) observations the question is: How does one account for trade flows with various trade frictions *and* the fact that there is little variation in comparable price indices across countries? Frictions in goods trade suggests there should be variation in prices and trade fictions play an important role in understanding goods trade; see Anderson and van Wincoop (2004). Yet, Hsieh and Klenow (2007) argues that the aggregate price data suggests otherwise.[2]

I show that to understand trade flows and comparable price indices, poor countries must face systematic trade frictions to export their goods relative to rich countries.[3]. In the sense that these results emphasize poor countries ability to export, the results here are complementary to Hsieh and Klenow (2007). In contrast to their conclusion that trade frictions play no role, the results here suggest that they do play a critical role — they are just of a different type either Eaton and Kortum (2001) or Hsieh and Klenow (2007) consider. Furthermore, the results here suggest that the failure of Eaton and Kortum (2001) to correctly replicate prices arises from their modeling of trade costs. If they had employed the trade cost function advocated here with an exporter fixed effect, their estimated prices would have been consistent with the data as discussed in Hsieh and Klenow (2007).

A final paper of note is Helpman, Melitz, and Rubinstein (2007) which studies asymmetries in trade flows as well. They build on the model of Melitz (2003) with fixed costs and firm heterogeneity and derive a modified gravity equation to study similar asymmetries in trade flows. Their formulation introduces an addition term reflecting several biases they identify in the traditional estimation of trade flows. The quantitatively important bias identified results from the fact that standard gravity formulations do not correct for the number or fraction of firms that export, i.e. the extensive margin. This paper and that of Helpman, Melitz, and Rubinstein (2007) are different models and approach the data in very different ways. However, the result discovered in this paper — asymmetry in trade costs — plays a similar role by adjusting the number of goods (which is the the extensive margin is this model) that a country can export to a given destination and I show this effect is quantitatively important to understanding bilateral trade flows.

The paper proceeds as follows. Section 2 outlines the model. Section 3 describes the data and various issues surrounding it. Section 4 presents the findings regarding the recovered trade costs. Section 5, details a richer model, calibration and decomposition strategy, and the quantitative results. Section 6 describes and implements a trade cost function to model these observations. Section 7 concludes.

[2]A similar dichotomy regarding factor trade arises in Caselli and Feyrer's (2007) study of cross-country variation in the marginal product of capital. Given the observations in Lucas (1990), authors have argued for credit frictions explaining why capital does not flow to poor countries. Yet, Caselli and Feyrer (2007) points out that once the marginal product of capital is appropriately measured—there is little room for credit frictions to play a role.

[3]I consider a broader set of goods relative to Eaton and Kortum (2001) and Hsieh and Klenow (2007). But the key properties of the data are quite similar to those studied in Eaton and Kortum (2001) and Hsieh and Klenow (2007).

2 The Model

This section details a general model that is specific enough to derive a "gravity" style relationship. In the economy there are N countries. Each country has a tradable goods sector and tradable goods are useful only in aggregate. Section 5 provides a more detailed economy, but what is presented below is sufficient to study trade flows and relative prices.

2.1 Tradable Goods Sector

As in Dornbusch, Fischer, and Samuelson (1977) there is a continuum of tradable goods indexed by $x \in [0, 1]$ produced and traded. Efficiency levels in the production of good x vary across goods and countries and are denoted $z_i(x)^{-\theta}$. θ is common across countries.

In each country i, $c_i p_i$ is the cost of inputs needed to produce one unit of good x and is the same across goods. Furthermore, production technologies exhibit constant returns to scale implying the unit cost to produce one unit of good x for the home market is $z_i(x)^{\theta} c_i$. Furthermore, production in the market is competitive implying prices are set equal to unit cost.

There are variable costs to shipping goods between countries and they are modeled using the standard iceberg assumption. That is positive trade costs imply $\tau_{ij} > 1$ of good x must be shipped from country j for one unit to arrive in country i. In addition, τ_{ii} is normalized to one for each country. These assumptions on technologies and trade costs imply that the unit cost for country i to deliver a good to country j is:

$$p_{ji}(x) = z_i(x)^{\theta} \tau_{ji} c_i.$$

2.2 Distribution of Efficiency Levels

Following Eaton and Kortum (2002), I parameterize the model by treating $z_i(x)$ as an idiosyncratic random variable. In the setup above, I follow Alvarez and Lucas (2007) and assume that $z_i(x)$ is distributed independently and exponentially with parameter λ_i which varies across countries. This is analogous to a Type II extreme value or Fréchet distribution as in Eaton and Kortum (2002).

In the production of tradable goods, each country's λ_i governs its average level of efficiency. A country with a relatively larger λ_i is, on average, more efficient. Given a draw $z_i(x)$, it is taken to the power $-\theta$ yielding good x's efficiency level. θ controls the dispersion of efficiency levels. Specifically, the coefficient of variation for each country's distribution of efficiency levels is controlled only by θ. A larger θ yields more variation in efficiency levels relative to the mean. In this sense θ controls the degree of comparative advantage and a country's λ_i determines its absolute advantage.

Relabeling each good x by its efficiency level z, tradable goods are purchased in amounts $m_i(z)$ and consumed in aggregate. Goods are aggregated via a CES production function with elasticity η. In country i, firms producing the aggregate tradable good face the problem of minimizing the cost of producing q_i. The solution to this problem yields the following price of the aggregate tradable good:

$$p_i = \left[\int_0^{\infty} p_i(z)^{1-\eta} \pi(z) dz \right]^{\frac{1}{1-\eta}}$$

in which $p_i(z) = \min[p_{i1}(z), ..., p_{iN}(z)]$ and $p_{ij}(z)$ is the price country i can purchase tradable good z from country j including costs to trade.

2.3 Trade Shares, Prices, and Trade Costs

This section derives a simple relationship between trade shares, prices, and trade costs. This relationship provides the foundation for studying bilateral trade flows and trade costs. Details concerning their derivation can be found in Waugh (2007).

Trade Shares: X_{ij} is the fraction of all goods country i imports from country j. Since there is a continuum of goods, computing this fraction boils down to finding the probability that country j is the low-cost supplier to country i given the joint distribution of efficiency levels, prices, and trade costs for any good z. The result is the following expression for trade shares:

$$X_{ij} = \frac{(c_j \tau_{ij})^{\frac{-1}{\theta}} \lambda_j}{\sum_{\ell=1}^{N} (c_\ell \tau_{i\ell})^{\frac{-1}{\theta}} \lambda_\ell}. \tag{1}$$

Note that the sum across j for a fixed i must add up to one.

Price Index: Given the technologies, each country faces the following price of tradable goods for each country i:

$$p_i = \Upsilon \left[\sum_{\ell=1}^{N} (c_\ell \tau_{i\ell})^{\frac{-1}{\theta}} \lambda_\ell \right]^{-\theta}, \tag{2}$$

where Υ is a collection of constants.

Recovering Trade Costs: To provide a relationship between trade costs and observable data, two observations are necessary. First, notice that the price index (2) is related to the denominator in the expression for the trade share (1). Exploiting this relationship and abstracting from common constant terms, a simplified expression for the fraction of goods country i purchases from country j is:

$$X_{ij} = \frac{(c_j \tau_{ij})^{\frac{-1}{\theta}} \lambda_j}{p_i^{\frac{-1}{\theta}}}.$$

The second observation is that by dividing X_{ij} by X_{jj}, or the fraction of goods country j purchases from home, the unit cost parameter c_j and technology parameter λ_j cancel resulting in the following expression:

$$\frac{X_{ij}}{X_{jj}} = \left(\frac{p_i}{p_j}\right)^{\frac{1}{\theta}} \tau_{ij}^{\frac{-1}{\theta}}. \tag{3}$$

Equation (3) relates the fraction of goods country i imports from country j adjusted by how much country j buys from home to differences in aggregate price indices and the cost to trade. First, not the adjustment of the bilateral trade share X_{ij} by X_{jj} controls for a country's economic size. To see this, consider the case when there are no trade costs. In this case there is complete specialization with $X_{ij} = X_{jj}$ and these values equal to a counties GDP relative to the rest of the World. Furthermore, with no trade costs prices are equalized equation (3). The importance of these observations is that though the trade share X_{ij} may be small—without adjusting this value by the home share nothing can be inferred about trade costs or relative price differences.

Next abstract from the adjustment by X_{jj}, equation (3) says that if $p_i > p_j$, then country i has incentives to purchase relatively more goods from country j because they are cheaper resulting in a larger import share. Or, if trade costs between country i and j are large, then country i has less incentive to purchase a good from country j resulting in a smaller import share, holding all else constant.

A key feature of equation (3) is that it resembles a reduced form gravity equation with multilateral resistance terms; see Anderson and van Wincoop (2004) which illustrates this relationship. A standard approach to estimating equation (3) is to take the logarithm of equation (3), assume a relationship between τ_{ij} and distance and other observable data, represent prices as country specific fixed effects, and estimate. Obviously, the result is that trade costs that are symmetric and least squares achieves this by manipulating the estimated country specific fixed effects resulting in implications for the modeled implied prices p_i.

An alternative approach is to note that in equation (3) two of the three objects—trade shares and aggregate price indices—are observable and hence trade costs may be recovered as a residual with out any restriction on the form of these costs. The basic idea in this paper is to discipline the implied prices with data and study the recovered trade costs in contrast to the standard approach to estimating equation (3).

3 Data

To recover the trade costs using equation (3), I must take a stand on the world economy and how the model corresponds to actual economies, construct aggregate bilateral trade shares and price indices of tradable goods, and take a stand on the parameter θ. I consider two model years of 1985 and 1996. Table 7 details the countries considered. 77 countries are in the sample and represent over 90 percent of World GDP in 1996.[4]

[4]The most important countries not included are Germany, due to data problems associated with East Germany's reintegration with West Germany, and Taiwan, again due to data problems as a result of political issues.

Trade Share Data: I assume that the tradable goods sector corresponds to manufactures. This is a simplification, but since nearly 80 percent of all merchandise trade is in manufactures this assumption is reasonable as a first-order approximation to reality.

I constructed trade shares X_{ij} following Bernard, Eaton, Jensen, and Kortum (2003). First, I compiled manufacturing bilateral trade data from Feenstra, Lipsey, and Bowen (1997) for the model 1985 and 1996. Aggregating across all 34 BEA manufacturing industry codes provides the aggregate value of manufactured goods each country purchases from each other. I then divided the value of country i's imports from country j by gross manufacturing production minus total manufactured exports (for the whole world) plus manufactured imports (for only the sample) yielding bilateral trade shares. Basically, this is just a way to map production and trade data into the unit interval, by dividing inputs from country j used in country i divided by total inputs used in country i. Gross manufacturing data is either from UNIDO (2005), OECD, or the World Bank; see Waugh (2007) for details regarding the year 1996.

One may be concerned with the absence of agriculture. However, the data does include processed agricultural goods. Most of the gross manufacturing data I employ corresponds with manufacturing as defined by ISIC revision 2 and the bilateral trade data is an approximation of this categorization as well. Roughly any manipulated agricultural good shows up as manufacturing. For example, code number 1531 which is "Manufacture of grain mill products" is considered an manufactured product. Basically this activity encompasses the process of turning gains and mills into edible and useful products. In contrast, goods not included are items such as code number 0111 or "growing of cereals and other crops n.e.c." This activity basically encompasses only the of growing the grains.

In table 8, I present the matrix of trade shares for selected countries in the sample. A row denotes the exporting country and a column denotes the importing country. Relative to the discussion of equation (3), there are two important features to note. First, notice the predominantly large values lying along the diagonal of the trade share matrix. These are the data on X_{ii} or the fraction of goods each country purchases from home. The important observation is that there is little variation in the X_{ii}s relative to a country's share of World GDP. If the world was close to frictionless trade then the model implies that X_{ii} equals a country's share of World GDP. Taking the sample as the World, Zaire's share of World GDP is 0.02 percent yet Zaire's home trade share is 51 percent. As another example, the U.S.'s share of World GDP is 30 percent, yet the U.S.'s home trade share is 83 percent.

The second feature is the distinct asymmetry in bilateral trade shares between rich and poor countries. This is seen by contrasting the upper right quadrant (encompassing poor countries imports from rich countries) with the lower left quadrant of table 8 (encompassing rich countries imports from poor countries). Poor countries import a significantly larger share of goods from rich countries, than rich countries import from poor countries. For example, imports from Zaire account for only 0.003 percent of the U.S. market, yet imports from the U.S. account for 2.93 percent of Zaires market. This difference is a factor of 1000 and is a moderate example.

For a representative rich and poor country denoted r and p consider the value:

$$\frac{X_{rp}}{X_{pr}}\frac{X_{rr}}{X_{pp}},$$

and note from equation (3) this value is only a function of relative prices and relative trade cost. Frictionless trade implies this value should equal one. In the case of the U.S. and Zaire, this value is about 2/1000. Only two items can rationalize this value. Differences in the price of tradable goods or differences in trade costs. The next section discusses data on prices.

Price Data: In the model, the prices p_i are the aggregate price indices of tradable goods. Note, that these are *tradable* goods not *traded* goods since in equilibrium some goods may not be traded. Furthermore, since the bundle of tradable goods is the same for all countries, a key concern is that the data is comparable across countries. To construct data on these prices, I employed price data from the U.N International Comparison Program (ICP). This program collects prices on goods and services in various countries and "benchmark" years which are ultimately used in the construction of the Penn World Table. The most relevant feature regarding their collection is the explicit goal of comparability. That is prices are supposed to be for the same or similar goods and the baskets of goods are the same across countries. Furthermore, these prices are national average prices, i.e. they are not collected only in cities but rural areas as well. In these respects, these prices are different than simple consumer price indices which are often not comparable between countries because they have different goods, different baskets, and often are only collected in major cities (See paragraph #42 and #46 in United Nations International Comparison Programme (2003)).

To construct tradable price indices, benchmark data for the years 1985 and 1996 were obtained from the Penn World Table website (http://pwt.econ.upenn.edu). Data on prices are provided at disaggregate categories for each benchmark year. From this data, only categories which best correspond with the bilateral trade data are included. For example, the category "Medical and Health Services" is excluded on the basis that services are not included in the bilateral trade data used. In contrast, "Alcoholic Beverages" are included since it corresponds with the BEA category 2 in the Feenstra, Lipsey, and Bowen (1997) data set.[5]

From the benchmark price data, I constructed the appropriate price indices of tradable goods.[6] Table 7 presents the constructed prices. Figures 1 and 2 plot the price of tradeable goods for 1985 and 1996 versus purchasing power parity adjusted GDP per worker data for that year. As

[5]There is no one to one mapping, so discretion is involved. Some categories seem to include items that are inherently non-traded, e.g. "Footwear and Repairs" which was included. At the current aggregation provided for 1996, this is unavoidable and PWT administrators are unwilling to provide me with any finer level of aggregation. The benchmark year 1985 provides prices at a more disaggregate level, yet for comparability between 1985 and 1996, only the same categories were considered.

[6]Not all the 77 countries are benchmark countries. The trade off I face is between a large sample of bilateral trade shares versus using only benchmark countries. I opted for more trade data. To construct price indices for non-benchmark countries, I imputed their values from information in the PWT. To do so, I regressed the constructed prices for the entire the benchmark table on the price of consumption (pc) and price of investment (pi) which is available for all countries directly from the PWT. Given the estimated coefficients, I imputed the price of tradable goods for non-benchmark countries by using the observed price of consumption and price of investment.

the figures illustrate, poorer countries have slightly lower prices of tradable goods. For benchmark countries in 1985 and 1996, the elasticity of the price of tradable goods with respect to income is 18 percent and 27 percent.[7] For the sample considered in this paper in 1985 and 1996, the elasticity of the price of tradable goods with respect to income level is 20 and 15 percent. My results are consistent with Kravis and Lipsey (1988) which document similar relationships between the price of tradable goods, price of non-tradeable goods, and level of development. Furthermore, Hsieh and Klenow (2007) study similar price indices for only investment goods and the elasticities I report are consistent with their findings.

Other Issues: To recover the trade costs, I must take a stand on the parameter θ. As discussed, θ controls the dispersion in efficiency levels across intermediate goods for all countries. I selected a value of 0.15, which is the value used in Alvarez and Lucas (2007) as a baseline. This value and the distributional assumptions imply a coefficient of variation of approximately 0.22 for each country's efficiency levels. The selected baseline value of θ lies in the middle of empirical estimates. Eaton and Kortum (2002) found a range of 0.078 and 0.28 depending on their approach in estimating θ. Furthermore, Eaton and Kortum (2002) and Anderson and van Wincoop (2004) showed how θ is related to the elasticity of substitution in an Armington aggregator model of international trade. Anderson and van Wincoop (2004) claimed reasonable values for this elasticity are between 5 and 10, which implies a range for θ of 1/9 and 0.25.

A final issue is that, in aggregate, every country should purchase some non-zero amount of goods from all other countries. In fact, the bilateral trade matrix has many recorded zeros.[8] For the sample considered there are 5,929 possible trading combinations; 1,610 (27 percent) show no trade at all. The model makes a clear statement regarding these instances; the cost to trade between these countries is infinity. I follow the model and treat these instances as it suggests.

4 Asymmetric Trade Costs

To study the trade costs implied by the pattern of bilateral trade, rearranging equation (3) provides the following relationship to recover trade costs:

$$\left(\frac{X_{ij}}{X_{jj}}\right)^{-\theta} \frac{p_i}{p_j} = \tau_{ij}.$$

In the following sections, I discuss the levels of these trade costs, their asymmetry, and some robustness exercises.

[7] To contrast this relationship, for benchmark countries in 1985 and 1996 the elasticity of the price of non-tradable goods with respect to income is 47 percent and 60 percent where non-tradable goods are defined as the compliment of tradable goods.

[8] It should be emphasized this does not imply zero trade between these country pairs, but just that the minimum threshold for recording the data was not met.

Table 1: Trade Costs, Summary Statistics

Year	Median τ_{ij}	Median OECD τ_{ij}	$\tau_{us,can}$	$\tau_{can,us}$
1985	2.82	1.99	1.62	1.19
1996	2.70	1.86	1.41	1.13

4.1 Summary Statistics

Table 1 presents summary statistics regarding the levels of trade costs. There are two features of interest. First, the recovered trade costs are large, but not unreasonably so. For example, the median trade cost for OECD countries is equivalent to an 86 percent tariff in 1996. Anderson and van Wincoop (2004) survey the literature and report that for a representative developed country, plausible trade costs fall in a range between 40-80 percent depending on the study and elasticities of substitution. The results here are consistent with their survey.

Table 1 also reports the trade cost for both sides of the U.S-Canada border. These costs are lower than the median for OECD countries. Furthermore, it is slightly less expensive for Canada to import a good from the U.S., than it is for the U.S. to import a good from Canada. Anderson and van Wincoop (2003) argue that their estimates (under their assumption of symmetric trade costs) can be interpreted as a geometric average of trade cost between the two countries (see footnote 12, page 175). Their estimate for all trade barriers between the U.S. and Canada is 46 percent (see Anderson and van Wincoop (2004), page 717, Table 7). For comparison, when the estimates in table 1 are adjusted for differences in elasticities of substitution, the geometric average of the U.S.-Canada trade cost in 1996 is 27 percent—almost 50 percent lower then their estimates.

This finding is related to the arguments of Balistreri and Hillberry (2007). They argue that the modeling of trade costs affects Anderson and van Wincoop's (2003) multilateral resistance terms and hence effects their estimates of the border effect. Here Anderson and van Wincoop's (2003) "inward multilateral resistance" term corresponds with the price data I employ. Table 1 suggests that when trade costs and the "inward multilateral resistance" terms are disciplined by price data, then the border effect is reduced by 50 percent relative to Anderson and van Wincoop's (2003) results.

4.2 Asymmetry

A simple way to study asymmetry is for a fixed country i plot:

$$\frac{\tau_{ij}}{\tau_{ji}}, \tag{4}$$

and examine how this relationship varies between all j countries relative to their level of development. Recall, i is the importing country and j is the exporting country. Note that if trade costs are a multiplicative function of symmetric observable data (e.g. distance, shared border, shared language, etc.) as the gravity literature often assumes , then $\frac{\tau_{ij}}{\tau_{ji}} = 1$, at least on average.

When trade costs are not symmetric, (4) has the following interpretations depending if (4) is greater than or less than one. For example, if $\frac{\tau_{ij}}{\tau_{ji}} > 1$, then it is relatively more expensive for country j to export a good to country i, than for country i to export a good to country j. Second, if $\frac{\tau_{ij}}{\tau_{ji}} < 1$, than it is relatively more expensive for country j to import a good from country i, than for country i to import a good from country j.

Figure 3 plots equation (4), for the U.S. fixed as country i, versus purchasing power parity GDP per worker data for all countries j in 1985 and 1996. In figure 3 one features stands out: Costs to trade are not symmetric and they deviate from symmetry systematically given a country's level of development. Since almost all values lie above the dashed horizontal line depicting symmetric trade costs, this says most countries face relatively higher costs to export to the U.S. market. Furthermore, the poorer a country is, the more difficult it is to export to the U.S. That is the U.S. appears to be a relatively closed economy and increasingly so the poorer the country.

Consider figure 4 which plots equation (4), for China fixed as country i, versus income level data for all countries j in 1985 and 1996. As in figure 3, a similar pattern emerges. Relative trade costs deviate from symmetry systematically given a country's level of development. However, there is an important difference. For the U.S., almost all relative trade costs lie above the value one. For China this is not the case. Approximately half the data points lie above one and the rest below. For example, for countries with an income level greater than approximately 1/4 the U.S. level, it appears relatively costly for these countries to import a good from China.[9] Yet, for destination countries with income levels less than 1/4 the U.S. level the opposite is true, it appears relatively costly for these countries to export to China. Roughly, China faces difficulties exporting to countries more developed than itself and less difficulties to countries less developed than itself.

Figure 5 plots equation (4) for Malawi fixed as country i versus income level data for all countries j in 1985 and 1996. Again, as in figures 3 and 4, there is a strong negative correlation between income level and a country's relative trade cost with Malawi. Yet, in contrast to the U.S. or China, almost all Malawi's relative trade costs lie below one. That is for all destinations, it is relatively costly for these countries to import a good from Malawi.[10]

Between the observations in figures 3-5 a pattern emerges. Relative trade costs deviate from symmetry in a systematic way given a country's level of development. More specifically, the poorer a country is, it is relatively more difficult for that country to export to any destinations and increasingly so the richer the destination country.

To illustrate this pattern for all countries, I estimated the following relationship between relative

[9] It would be interesting to perform a similar exercise but with more recent data to assess claims regarding China's aggressive export behavior. Unfortunately, the key data limitation are prices.

[10] Another difference between figures 3 and 4 and figure 5, is that there are less values. This is because of the high number of zero trade flows Malawi faces. Helpman, Melitz, and Rubinstein (2007) provide a framework that can account for zero trade flows in one or both directions between countries.

Table 2: Robustness of Price Elasticity, 1996

	ρ_τ	ρ_X	ρ_p
Data	-0.80	2.30	-0.23
$p_i = p_j$	-0.34	2.30	0
Symmetry	0	2.30	0.17

trade costs and income levels:

$$\log\left(\frac{\tau_{ij}}{\tau_{ji}}\right) = \alpha_\tau + \rho_\tau \log\left(\frac{y_j}{y_i}\right), \tag{5}$$

in which ρ_τ is the elasticity of asymmetry with respect to income level. For 1996 and using least squares, the estimate of ρ_τ is -0.80 and is precisely estimated. The negative relationship confirms the observations in figures 3-5, the poorer a country is the more difficult it is to export to richer countries. For 1985, the estimate of ρ_τ is similar at -0.83. I also estimated (5) for each country fixed, i.e. an estimate of the elasticity between income and relative trade costs seen in figures 3-5 for each country. The mean value in 1996 is -0.87, slightly higher than the pooled regression. The results for 1985 are similar as well. For all countries, there is a systematic deviation from symmetry with a roughly constant negative relationship between relative trade costs and income level.

The intuition behind this result is straight forward—two pieces of data and one equation are all that need to be understood. First, the observations made from table 8 show that between rich and poor countries bilateral trade volumes adjusted for each countries economic size are severely asymmetric. The elasticity ρ_X discussed below in table 2 confirms this observation and shows that this asymmetry varies systematically with a country's level of development. Second, figures 1 and 2 show that poor countries face only slightly lower prices relative to rich countries. Then equation 3 implies that to given differences in trade volumes between rich and poor countries and because relative price differences are small, trade costs must account for a majority of this difference and they must be systematically asymmetric with poor countries facing relative difficulties to exporting their goods.

4.3 Robustness and Discussion

This finding relies on how prices co-vary with a country's level of development. There is some debate regarding the accuracy of prices collected from the International Comparison Programme; see the discussion in Hsieh and Klenow (2007). This is a difficult criticism to evaluate given publicly available data. However, a simple question to ask is: How wrong would the prices have to be to change this result?

A simple way to answer this question is in terms of the elasticity of prices with respect to level of development. Recall that $\frac{\tau_{ij}}{\tau_{ji}} = \left(\frac{X_{ij}X_{ii}}{X_{ji}X_{jj}}\right)^{-\theta}\left(\frac{p_i}{p_j}\right)^2$ and define ρ_X as the elasticity of $\frac{X_{ij}X_{ii}}{X_{ji}X_{jj}}$ with respect to $\frac{y_j}{y_i}$. Furthermore, define ρ_p as the elasticity of $\frac{p_i}{p_j}$ with respect to $\frac{y_j}{y_i}$. This implies that the estimate of ρ_τ from equation (5) is given by:

$$\rho_\tau = -\theta \rho_X + 2\rho_p. \tag{6}$$

Given equation (6), I can ask the following question: What price elasticity, ρ_p, is necessary to change my results?

Table 2 presents several calculations. The first row illustrates the decomposition of (6) for the data in 1996. The second row in table 2 considers the case if prices were equalized. Here even if prices were actually the same across countries, trade costs would still be systematically asymmetric with respect to a country's level of development. The third row in table 2 considers the case to yield no systematic asymmetry in trade costs. In this case, the elasticity of prices with respect to income level would have to be 0.17 almost the complete opposite of the value seen in the data.

To illustrate the magnitude of this result, consider a country with 1/30 the income level of the U.S. In the data, this country would have a tradable goods price approximately 1/2 the U.S. level. In contrast, this thought experiment suggest that a country with 1/30 the U.S. income level should face a tradable good price 1.8 times larger than the U.S. value. That is these prices must systematically mismeasured and mismeasured by more than 300 percent for this result to disappear. Overall, the calculations in table 2 suggest that for this result to disappear the magnitude of systematic measurement error by the ICP would have to be dramatic.

A second question is: Are these prices appropriate proxies for p_i in the model? Anderson and van Wincoop (2004) in the context of a single good model with complete specialization argue that the use of aggregate price indices are inappropriate.[11] They claim that these price indices are best thought of as "an ideal index of trade costs". First, the framework used here is a multi-good model with incomplete specialization (in the presence of trade costs) and includes non-traded goods. Hence it matches up with data better than the frameworks they operate in. Independent of this observation, there is no inconsistency here—the price indices imply that it is easy for poor countries to import goods—the trade costs recovered reflect this. Hence the price indices appropriately summarize the trade costs recovered here.

5 Is Asymmetry Quantitatively Important?

The previous section illustrated the pattern trade costs must take to rationalize bilateral trade flows and relative prices. However, plotting this pattern says nothing about its quantitative importance in determining bilateral trade flows. For example, though poor countries face systematic difficulties to export, they may be quantitatively small relative to distance. To distinguish among these possibilities, the next section imposes more structure on the model. Section 5.2 discusses the

[11] Their argument comes in the context of the criticism of Balistreri and Hillberry (2006). They argue that the Anderson and van Wincoop (2003) estimation predicts that the cost of living in Canada is 24 percent higher than in the U.S. and show evidence to the contrary; see the discussion in section 4.1. Other papers have used price indices in a gravity model, see Baier and Bergstrand (2001) which studies the growth of world trade.

calibration of each countries technology parameter λ_i. Section 5.3 introduces additional data. Section 5.4 decomposes the recovered trade costs into symmetric and asymmetric components. Section 5.5 presents the results of the quantitative exercise.

5.1 Closing the Model

To close the model, I assume each country has two sectors, an tradable goods sector and a final goods sector. Final goods are are non traded and produced using capital,labor and the aggregate tradable good with a Cobb-Douglas technology. For the purposes in this paper, this is all the information required. Within each country i, there is a measure of consumers L_i. Each consumer has one unit of time supplied inelastically in the domestic labor market and are endowed with capital supplied to the domestic capital market. Furthermore, each consumer has preferences only over the final good which is non-traded. In the following, all variables are normalized relative to the work force in country i.

Tradable Goods: In country i, capital k_i, labor n_i, and the aggregate intermediate good q_i are combined by the following nested Cobb-Douglas production function to produce quantity $m_i(x)$:

$$m_i(x) = z_i(x)^{-\theta}[k_i^{\alpha} n_i^{1-\alpha}]^{\beta} q_i^{1-\beta}.$$

Power terms α and β control the factor shares and are the same across countries. These technologies imply the equilibrium unit cost function for country i to supply country j with one unit of good x is:

$$p_{ji}(x) = z_i(x)^{\theta} \tau_{ji} r_i^{\alpha\beta} w_i^{(1-\alpha)\beta} p_i^{\beta}$$

5.2 Recovering Technology

Functions (1), (2), and balanced trade allow for the computation of an equilibrium given the structural parameters of the model.[12] Recall that section 4 recovered trade costs for every combination of country pairs using prices and bilateral trade shares. The final parameter to recover is λ_i—each country's technology parameter.

To recover each country's λ_i, rearranging (1) and using (2) provides an expression for each country's home trade share:

$$X_{ii} \quad = \quad \frac{\left[k_i^{-\alpha\beta} w_i^{\beta} p_i^{(1-\beta)}\right]^{\frac{-1}{\theta}} \lambda_i}{p_i^{\left(\frac{-1}{\theta}\right)} \Psi}, \tag{7}$$

[12] Alvarez and Lucas (2007) (which the model here is a variant of) provide sufficient conditions for the existence and uniqueness of an the equilibrium.

Table 3: Common Parameter Values

Parameter	Description	Value
α	k's share	1/3
β	k and n's share in int. goods production	0.33
θ	variation in efficiency levels	0.15

Further rearrangement of (7) provides the expression:

$$\left(\frac{w_i}{p_i}\right) = \Psi \left(\frac{\lambda_i}{X_{ii}}\right)^{\frac{\theta}{\beta}} k_i^{\alpha}. \tag{8}$$

in which wages, deflated by the intermediate goods price, are a function of each country's home trade share and its capital-labor ratio.

Given equation (8), I can recover each country's λ_i as a residual since all other objections in (8) are observable. Specifically, each country's home trade share X_{ii} and price of tradable goods p_i are known and measured as discussed in section 4. I can also measure aggregate capital-labor ratios k_i and common parameter values such as α and β. Finally, with labor endowments L_i and bilateral trade shares X_{ij}, I compute an equilibrium wage rate for each country from balanced trade; see Waugh (2007). From equation (8), these steps allow for the recovery of λ_i as a residual.

The key property of recovering λ_is in this manner is that, by construction, the equilibrium model will exactly replicates observed data on bilateral trade and prices p_i.[13] Thus any variation in data on bilateral trade results from: (i) differences in endowments, (ii) differences in trade costs, or (iii) differences in technology parameters.

5.3 Additional Data and Common Parameter Values

This section outlines the additional data used and common parameter values selected. I used aggregate capital-labor ratios constructed using the perpetual inventory method using purchasing power parity adjusted investment rates in Heston, Summers, and Aten (2002). I used labor endowments from which are from information in Heston, Summers, and Aten (2002) as well.

I calibrated parameter values common to all countries as follows. I followed Alvarez and Lucas (2007) in selecting the value for η. Other then satisfying the necessary assumptions on technologies, this value plays no quantitative role. As shown in Waugh (2007), the model's structure aggregates up to a Cobb-Douglas production function with capital's share of α. Consistent with the income accounting literature, I set α equal to 1/3. An argument for setting α equal to 1/3 relies on Gollin (2002). He calculated labor's share for a wide cross-section of countries to be around 2/3.

[13] In Waugh (2007), I provide a method to recover λ_is with no assumptions regarding the trade costs—all that is needed is per-capita income data, country home shares, and balanced trade. In Waugh (2007), the recovered λ_is closely resemble a simple Solow residual. The recovered λ_is here are consistent with my findings in Waugh (2007).

For comparability, I calibrate the values β to 1996 data. The parameter β controls value added in intermediate goods production. With respect to the data used, β corresponds with value added in the traded manufacturing goods sector. I measured β from input-output tables for OECD countries in 1996 available at: http://www.sourceoecd.org. The average value added in the manufacturing goods sector is 0.33 and is consistent with previous models such as Yi (2003) which employ an input-output production structure.

5.4 Decomposing Trade Costs

To asses the importance of asymmetric trade costs relative to symmetric trade costs, I must take a stand on what describes the symmetric component of the recovered trade costs. I follow the gravity literature and assume the symmetric component is some function of observable data and estimate the relationship. Specifically, I assume that:

$$\log(\tau_{ij}) \quad = \quad \rho_d \ \log \text{distance}_{ij} + \text{border}_{ij} + \text{colony}_{ij} + \text{language}_{ij} + \text{im}_i + \text{ex}_j + \epsilon_{ij} \tag{9}$$

Here ρ_d is the elasticity with respect to distance.[14] The effects of sharing a border, colonial relationship (previous or current), and language are recovered as coefficients on dummy variables when these relationships are satisfied. As mentioned this specification is standard in the gravity literature and inherently symmetric. Define these values as the symmetric component of trade costs τ_{ij}^s.

The terms im_i and ex_j picks up the systematic asymmetric component through importer and exporter fixed effects. Note that in standard estimation of gravity models it is impossible identify both these effects. Define the sum of these values as the asymmetric component of trade costs τ_{ij}^a. Finally, ϵ_{ij} is assumed to have zero mean and is orthogonal to the regressors. To summarize, by estimating equation (9), I am decomposing the trade costs recovered from section 4 into a symmetric component τ_{ij}^s, systematic asymmetric component τ_{ij}^a, and some noise ϵ_{ij}.

I used OLS to estimate (9) and table 4 presents the point estimates for the symmetric components and robust standard errors.[15] As is common in studying trade flows, distance plays a role—table 4 reports a distance elasticity of 0.15 for both 1985 and 1996. Disdier and Head (2006) perform a meta-analysis the distance elasticity and the estimates here are consistent with their results.[16] In addition to distance, shared borders, colonial relationship, and language all influence trade costs to varying degrees and are precisely estimated.

Also in table 4 are estimates from estimating the gravity formulation in (3) for 1996 consistent

[14] The distance measures used to estimate the symmetric component of trade costs are in kilometers from capital city in country i to capital city in country j calculated by the great circle method. These measures, border, colony, and language data are from from Centre D'Etudes Prospectives Et D'Informations Internationales (http://www.cpeii.fr).

[15] I experimented with the poisson pseudo maximum likelihood estimator advocated by Silva and Tenreyro (2006) and including instances where there where zero trade flows by estimating the inverse of (9)—the estimates are similar. An exception to note is when equation (3) is estimated including zero trade flows. In that instance, the distance elasticity is substantially lower similar to the findings of Silva and Tenreyro (2006).

[16] The elasticity they study is actually $\frac{-\rho_d}{\theta}$.

Table 4: Symmetric Trade Cost Estimates

Effect	1985 Est.	1985 S.E.	1996 Est.	1996 S.E.	1996 Gravity—Eq (3) Est.	1996 Gravity—Eq (3) S.E.
ρ_d	0.15	0.002	0.15	0.002	0.13	0.002
Border	−0.13	0.001	−0.17	0.001	−0.19	0.11
Colony	−0.14	0.001	−0.07	0.001	−0.27	0.09
Language	−0.11	0.001	−0.17	0.001	−0.03	0.05
SSR	184		184		18,867	
TSS	6,531		3,300		29,585	
σ_ϵ	0.05		0.05		4.53	

with standard approaches. That is prices are represented as country fixed effects and trade costs are a function of distance, shared border, language, and colonial ties. The distance elasticities are similar, however, the estimates for shared border, language, and colonial ties are different and are not precisely estimated. Consistent with the discussion in section 4.3, the estimated prices are counter-factually higher for poor countries relative to rich countries. For example, the elasticity between the implied prices and income per worker is −0.14 percent in contrast to the elasticity in the data of 27 percent for 1996. The intuition is that since poor countries import a large share of goods from rich countries, yet rich countries import little from poor countries, a way to rationalize this observation with symmetric trade costs is to make prices high in poor countries and prices low in rich countries.

Helpman, Melitz, and Rubinstein (2007) is a related paper that studies asymmetries in trade flows and the estimation biases introduced by not incorporating them. They build on the model of Melitz (2003) with fixed costs and firm heterogeneity and derive a modified gravity equation. The key modifications are a Heckman selection effect when county pairs with zero trade flows are excluded, they find this bias to be quantitatively small. The second effect corrects for the number or fraction of firms that export, i.e. the extensive margin. Like their paper, the asymmetry in trade costs I identify play a similar role by adjusting the number of goods (which is the the extensive margin is this model) that a country can export to a given destination.

In contrast to Helpman, Melitz, and Rubinstein (2007), I find little bias in the distance elasticity when asymmetries are not taken into account. This is not a surprise since their "selection effect" is estimated as a function of distance. Thus, incorporating it into the gravity equation should induce a change in estimated distance elasticity relative to traditional estimates. However, the type of asymmetry discovered in this paper is highly correlated with income level and since income level is relatively uncorrelated with distance the estimates of the distance elasticity should be not be affected much if asymmetry is incorporated or not. As mentioned above, I do find that the point estimates of shared colonial relationship and language are substantially different relative to the gravity model with symmetric trade costs and their are efficiency gains.

Table 5: Percent of Variance in Bilateral Trade Explained

	1985			1996		
	Asym.	Tech.	Sym.	Asym.	Tech.	Sym.
Asym.	24.2	55.3	70.0	25.9	60.2	73.2
Tech.	—	25.6	52.8	—	28.0	51.6
Sym.	—	—	31.9	—	—	28.6

5.5 The Quantitative Importance of Asymmetry

To better understand the quantitative importance on asymmetry, I will follow an approach similar in spirit to Chari, Kehoe, and McGrattan (2007). Using a a prototype neoclassical growth model, they decomposed business cycle fluctuations into four wedges. A wedge is simply a friction that distorts the equilibrium decision of agents in the model. As an example, their efficiency wedge is simply total factor productivity. With the goal of understanding which wedges are quantitatively important and which are not in accounting for business cycle fluctuations, they are fed into the model—in combination and separately—and the resulting time series studied.

Similarly, in a standard model of bilateral trade, I recovered "wedges" which are departures from a symmetric multi-country model, with no trade costs. One deviation from this model is because countries have different endowments, capital and labor, and technology parameters, λ_i. And there are deviations from frictionless trade resulting in trade frictions, τ_{ij}. And I have decomposed these trade costs into symmetric, τ_{ij}^s and asymmetric components, τ_{ij}^a. Then by feeding in each of these different components—in combination and separately—I can study the quantitative importance of each in explaining the variation in bilateral trade.[17]

Table 5 presents the results from this exercise for both 1985 and 1996. Table 5 reports the cumulative percent variation in bilateral trade (from left to right and down to up) that different components can explain. For example, the upper right hand entry records the total variation in bilateral trade shares the systematic components can replicate, i.e. everything except for noise ϵ_{ij}. All together, endowments, symmetric components, asymmetric components, and technology parameters replicate about three-quarters of the variation in trade shares.

Diagonal entries in table 5 report the percent variance each component alone can replicate. Hence the row Asym and column Asym reports that the asymmetric component—only—replicates 24 and 26 percent of the variation in bilateral trade for 1985 and 1996. The row Sym and column Sym reports that the symmetric component—only—replicates 32 and 29 percent of the variation for 1985 and 1996.

Off diagonal entries report the cumulative variation combinations of components can explain.

[17] In all the exercises, endowments are fixed at calibrated levels. They account for less then 10 percent of the variation in bilateral trade flows. Furthermore, trade costs that were inferred to be infinity because of zero observed trade flows are kept fixed. Hence the following results are not a result of changing trade where there previously was none.

For example, row Asym and column Tech reports that the asymmetric component and differences in technology replicate 55.2 and 60 percent of the variation in bilateral trade for 1985 and 1996. Row Tech and column Sym reports that symmetric trade costs and differences in technology replicate 54.1 and 52.6 percent of the variation in bilateral trade for 1985 and 1996.

Depending upon the covariation between these measures, table 5 reports for 1996, symmetric trade costs accounts for between 13-29 percent of the variation in bilateral trade. Technology accounts for between 23-34 percent of the variation in bilateral trade. Asymmetry accounts for between 22-32 percent of the variation in bilateral trade.[18] Roughly, of the 75 percent of variation in bilateral trade which is not noise, traditional gravity variables account for a third, productivity differences account for a third, and asymmetry accounts for a third.

The implication of this result is that since cross-country productivity differences and systematic asymmetry in trade costs do not have simple explanations (at least relative to distance) our understanding of bilateral trade volumes is in fact quite limited despite the perceived succuss of the gravity model. That is observable symmetric relationships and endowments only explain at most 30 percent of the variation. The rest is attributed to a Solow residual and systematic asymmetry in trade costs.[19]

This is troubling because in the macro-development literature there is no consensus regarding the source of cross-country productivity differences; see the survey of Caselli (2005). Similar to the arguments of Hsieh and Klenow (2007), the combination of asymmetric trade costs and productivity differences is in fact a deeper puzzle. That is poor countries are not only unproductive at producing everything (i.e. small λ), the pattern of trade costs suggests they face systematic difficulties delivering goods for export to rich countries.

6 How to Model Asymmetry?

Using comparable prices and trade data I have uncovered features of the data not modeled before. Ideally one would like a modeling device so structural gravity models can replicate these facts. Consider the following trade cost function:

$$\log(\tau_{ij}) \quad = \quad \rho_d \ \log \text{distance}_{ij} + \text{border}_{ij} + \text{colony}_{ij} + \text{language}_{ij} + ex_j + \epsilon_{ij}. \tag{10}$$

[18]These findings are insensitive to different values for θ. I calibrated the model with θ set equal to 0.10 and 0.20 which are at the low and high end for empirically plausible values of θ. For both values in both years 1985 1996 the findings were similar.

[19]These results seem related to Trefler (1993) and Trefler (1995). He studies tests of the Heckscher-Ohlin-Vanek model which try to measure the factor content of trade. In these papers, if technologies are allowed to differ across countries and factors, then the tests of the Heckscher-Ohlin-Vanek model are satisfied. The papers of Trefler (1993, 1995) and this paper are different models (Heckscher-Ohlin and Ricardian) and are trying to understand different moments (the factor content of trade and bilateral trade volumes), but a similar idea remains. Productivity differences are the quantitatively important component to understanding either the factor content of trade or bilateral trade volumes.

This trade cost function is standard except for the incorporation of an an exporter fixed effect ex_j.[20] The motivation for this term are in figures 3-5. In these figures, it appears that a country's ability to export varies systematically with income level. This formulation is quite similar to Eaton and Kortum (2001, 2002) which assumed trade cost function with an importer fixed effect, i.e. replace ex_j with m_i in equation (10). Though these two formulations are similar, as the results below demonstrate they generate very different trade costs and prices.

To illustrate the performance of (10), for the year 1996 I estimated the following model:

$$\log\left(\frac{X_{ij}}{X_{ii}}\right) = S_j - S_i - \frac{1}{\theta}\log\tau_{ij},, \tag{11}$$

with least squares under alternative specifications for trade cost. The S_is are recovered as the coefficients on country specific dummy variables. The implied price indices are computable given the estimates of $\hat{S}$ and $\hat{\tau}$:

$$p_i = \Upsilon\left\{\sum_{j=1}^{N} e^{\hat{S}_j}\hat{\tau}_{ij}^{\frac{-1}{\theta}}\right\}^{-\theta}. \tag{12}$$

This is the approach employed in Eaton and Kortum (2001).[21]

Table 6 compares estimates employing the trade cost function of Eaton and Kortum (2001, 2002) on the left, my proposed trade cost function with an exporter fixed effect in the middle, and a symmetric trade costs function. Similar to the results in table 4, incorporating any type of asymmetry changes the point estimates increasing the effect of sharing a common language while reducing the effect of a common colonial relationship. Distance elasticities and shared border remain similar. Furthermore, the overall fit of the model improves significantly.

To examine the asymmetric pattern of the estimated trade costs, I regressed the estimated relative trade costs on relative income per worker as in (5). For the specification with an exporter fixed effect, the slope coefficient is -0.30, less then the value of -0.80 discussed in section 4 but of the correct sign. For the specification with an importer fixed effect as in Eaton and Kortum (2001, 2002), the slope coefficient is 0.30. It is the wrong sign relative to the results in section 4 suggesting poor countries face systematic difficulties importing goods.[22]

Figure 6 plots prices from equation (12) when trade costs are modeled with an exporter fixed effect, an importer fixed effect, and the data. The prices from the model with an exporter fixed effect are only slightly higher for poor countries relative to rich countries. The elasticity with respect to income level is approximately -0.04. This is different than the elasticity of 0.15 in the data. In contrast, the prices using an importer fixed effect of Eaton and Kortum (2001, 2002) are substantially higher than in the data. The elasticity of these prices with respect to income level is

[20] Again, the effects of sharing a border, colonial relationship , and language are recovered as coefficients on dummy variables when these relationships are satisfied.

[21] They actually use a Tobit approach to account for zero trade flows. For my purposes least squares is sufficient.

[22] Also note, this value is the exact opposite of the value with an exporter fixed effect. This is no fluke, but by construction.

Table 6: Alternative Formulations of Asymmetry to Estimate Eq (3)

Effect	Importer Fixed Effct. Est.	Importer Fixed Effct. S.E.	Exporter Fixed Effct. Est.	Exporter Fixed Effct. S.E.	Symmetry Est.	Symmetry S.E.
ρ_d	0.15	0.002	0.15	0.002	0.14	0.003
Border	−0.16	0.05	−0.16	0.05	−0.17	0.11
Colony	−0.08	0.03	−0.08	0.03	−0.27	0.10
Language	−0.16	0.02	−0.16	0.02	−0.03	0.05
SSR	820		820		18,814	
TSS	4,022		4,022		29,763	
σ_ϵ	2.00		2.00		4.52	

−0.29, seven times larger than the fixed effect model advocated here.

The trade cost function in equation (10) is not perfect—and it should not be. But relative to either a symmetric trade cost function or one with an importer fixed effect it performs significantly better and provides a simple way for otherwise standard structural gravity models to deliver the observations made in this paper.

The difficulties seen in figure 7 for the model with an importer fixed effect relates to Hsieh and Klenow's (2007) criticism of Eaton and Kortum (2001). Employing equations (11) and (12), Eaton and Kortum (2001) studied trade flows in investment goods and relative prices using an importer fixed effect. Similar to the results in figure 7, they find poor countries face systematically higher prices of investment goods relative to rich countries. This is in contrast to the data with poor countries facing similar prices relative to rich countries. They point out that this result is because poor countries are estimated—via their importer fixed effect—to have higher barriers to importing goods relative to rich countries. They interpret their results suggesting that ICP prices do not adequately control for quality differences and ignore additional costs to the use of machinery and equipment. Hsieh and Klenow (2007) revisit the data and argue that because these prices are roughly the same across countries, lower real rates of investment for poor countries are not a result of distortions such as high tax rates and or trade frictions as in Eaton and Kortum (2001). Instead poor countries face difficulties producing investment goods and exportables.

Between Eaton and Kortum (2001) and Hsieh and Klenow (2007), the question is: How does one account for trade flows with various trade frictions *and* the fact that there is little variation in comparable price indices across countries? The results in section 4 show that if poor countries face systematic trade frictions to export their goods relative to rich countries, one can reconcile both bilateral trade flows and international price indices. In the sense that these results emphasize poor countries ability to export, the results here are complementary to Hsieh and Klenow (2007). However, trade frictions play a critical role—they are just of a different form than Eaton and Kortum (2001) or Hsieh and Klenow (2007) considered. As figure 6 demonstrates, the trade cost function described in equation (10) provides an approach to account for both trade flows and prices across countries.

7 Conclusion

What data drive this asymmetry? I will pose several possible explanations, but this topic requires more research. A simply policy story behind this "asymmetry" in trade costs is the idea that though rich countries have, on average, low tariff and non-tariff barriers, certain sectors were/are still highly protected and poor countries are the predominant exporters in these sectors. A classic example is the U.S. textile industry. Examining the bilateral trade data sector by sector for several poor countries, a significant fraction of the U.S. imports were in the industry classified as "Apparel and Other Textile Products." Hence it may not be a surprise that the U.S. looks relatively protected towards poor countries. Anderson and van Wincoop (2004) provides some evidence regarding this explanation. More explicit evidence along this front is presented in Kee, Nicita, and Olarreaga (2006). They estimate trade restrictiveness indices from data on both tariff and non-tariff barriers for a large set of countries developed and undeveloped countries. They find that poor countries systematically face the highest trade barriers on their export bundle — similar to the asymmetry in trade costs here. Of course policies in poor countries could create this effect as well. Export marketing boards are one possible source of this distortion. These boards place a wedge between the price at which producers sell goods and the price at which the good is exported. Export marketing boards are prevalent in African countries.

Another potential explanation is discussed in Hummels (2001). In examining oceanic shipping schedules for a large set of countries, he finds that ships stoping at poor countries must make more frequent stops and the frequency of ships leaving poor countries is lower. These observations suggest that the time cost of shipping a good from a poor country is higher than shipping a good from a rich country which might imply the asymmetric pattern observed. Hummels, Lugovskyy, and Skiba (2007) also shows that poor countries pay substantially higher transportation costs than rich countries as a result of the composition of exports and market power by shipping firms.

Quality may be another explanation. More specifically, some modification of the arguments in Linder (1961) combining both demand and supply complementarities that depend on a country's level of development. I am currently exploring this topic.

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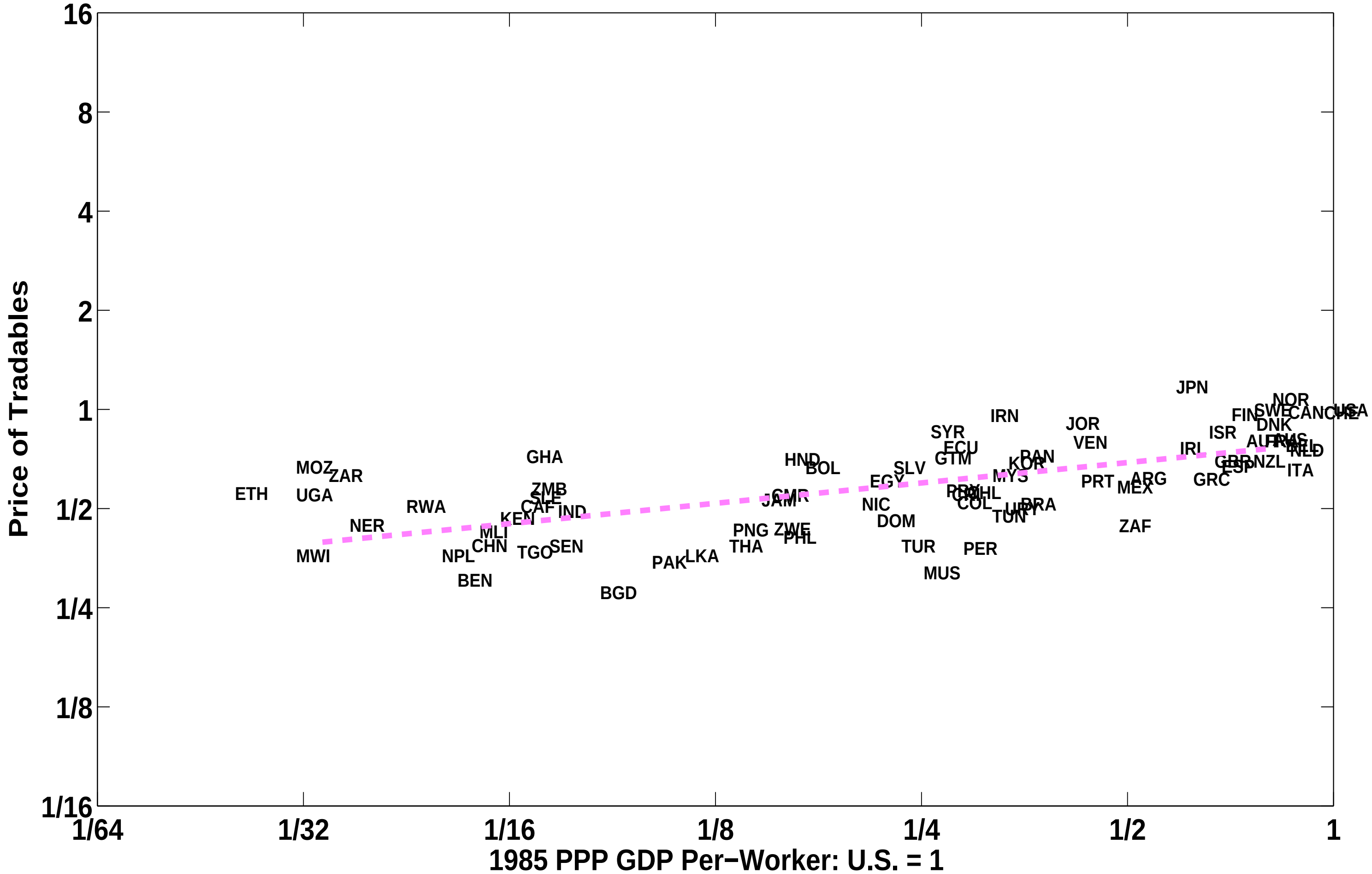

Figure 1: 1985 Price of Tradables versus Income Data

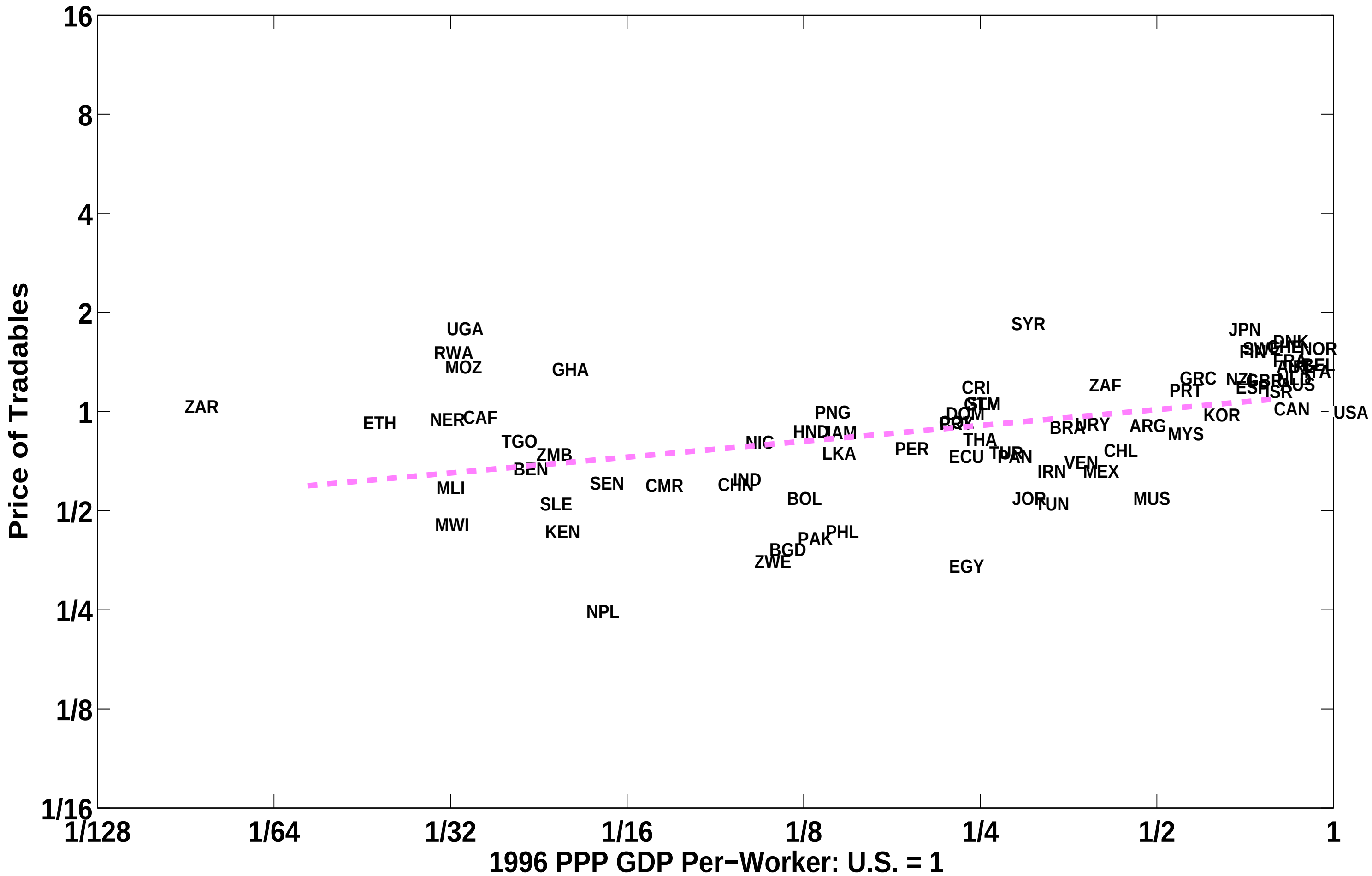

Figure 2: 1996 Price of Tradables versus Income Data

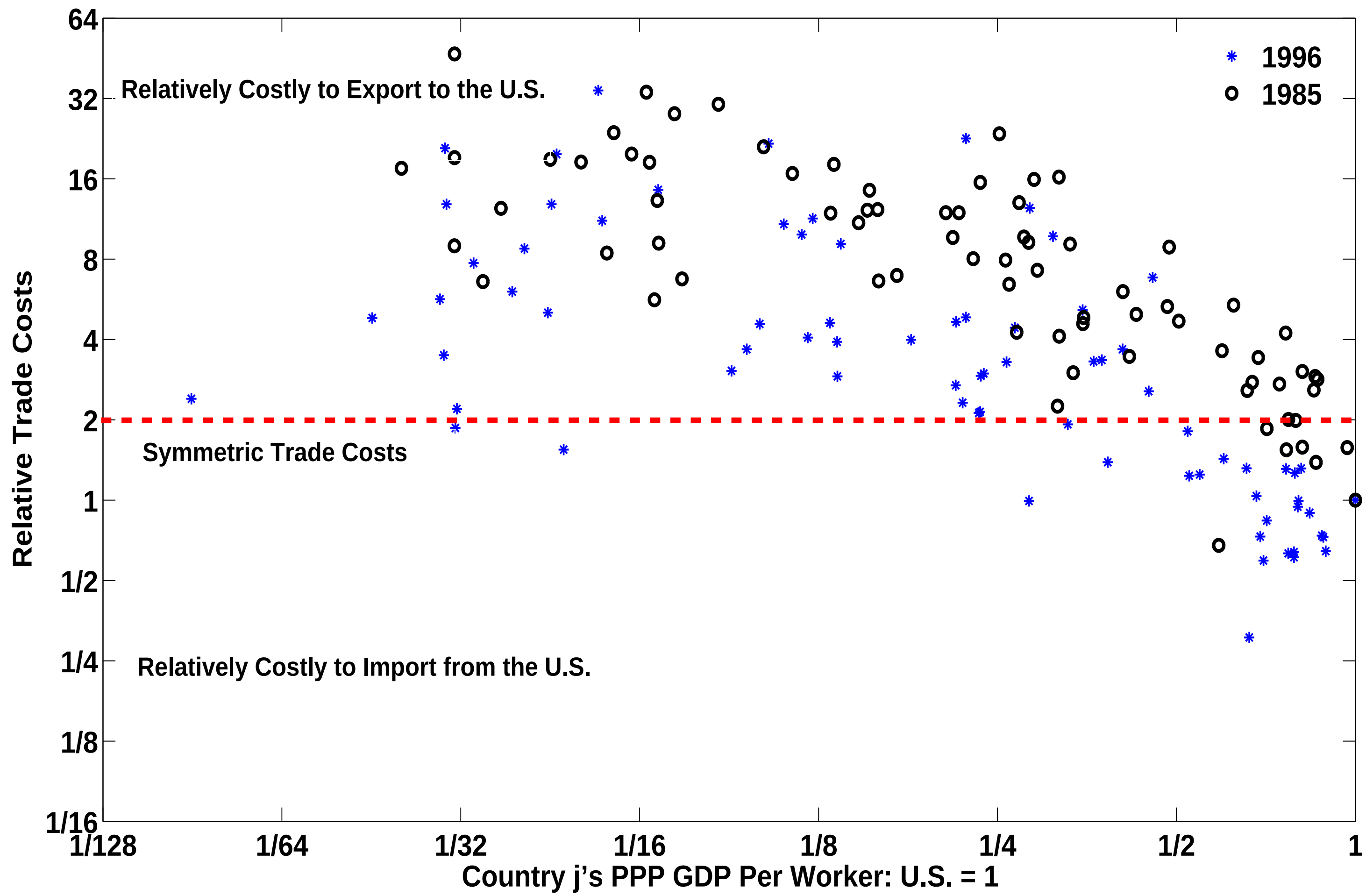

Figure 3: U.S. Relative Trade Cost: $\frac{\tau_{us,\ j}}{\tau_{j,\ us}}$.

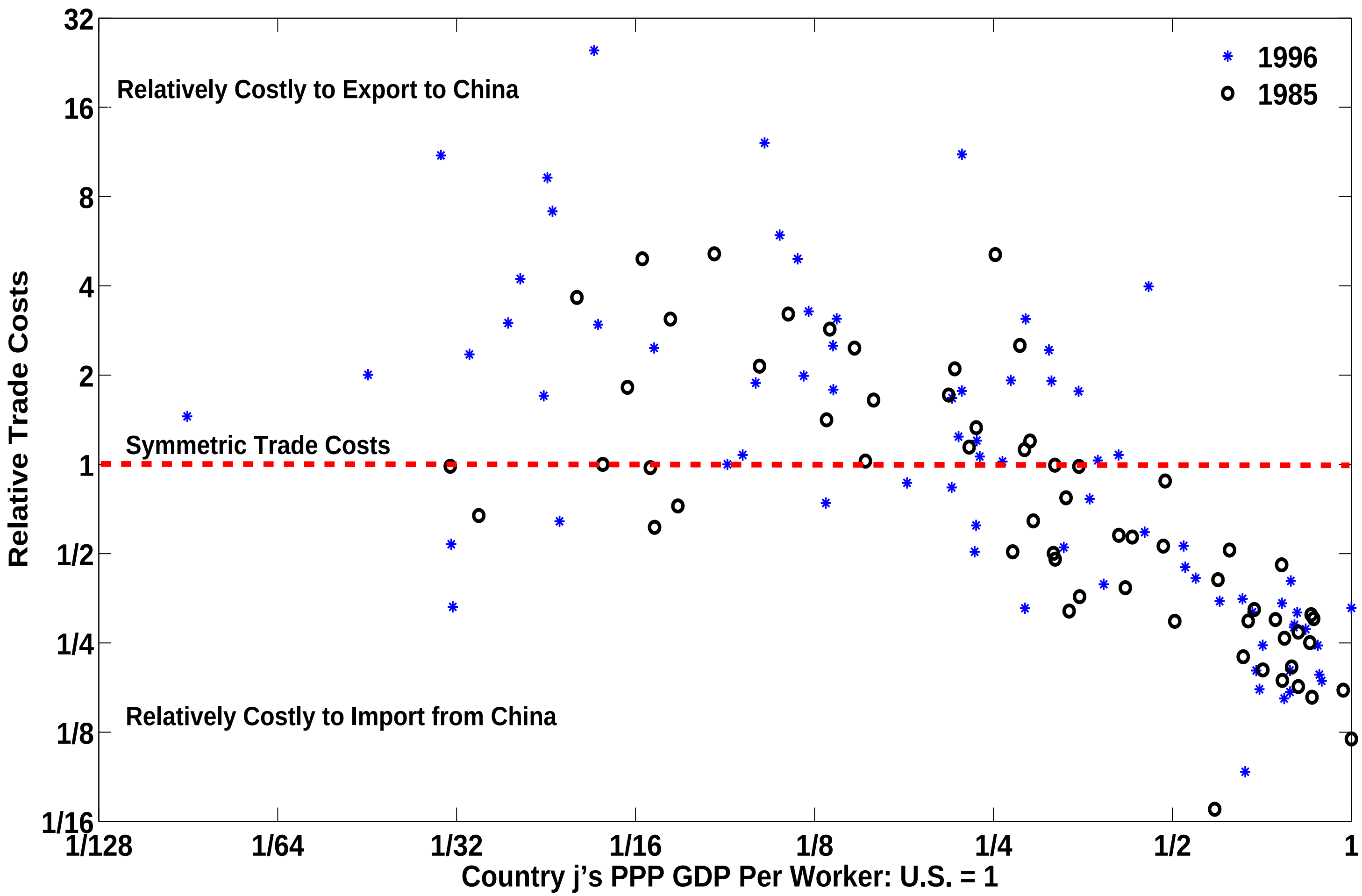

Figure 4: China Relative Trade Cost: $\frac{\tau_{china,\ j}}{\tau_{j,\ china}}$.

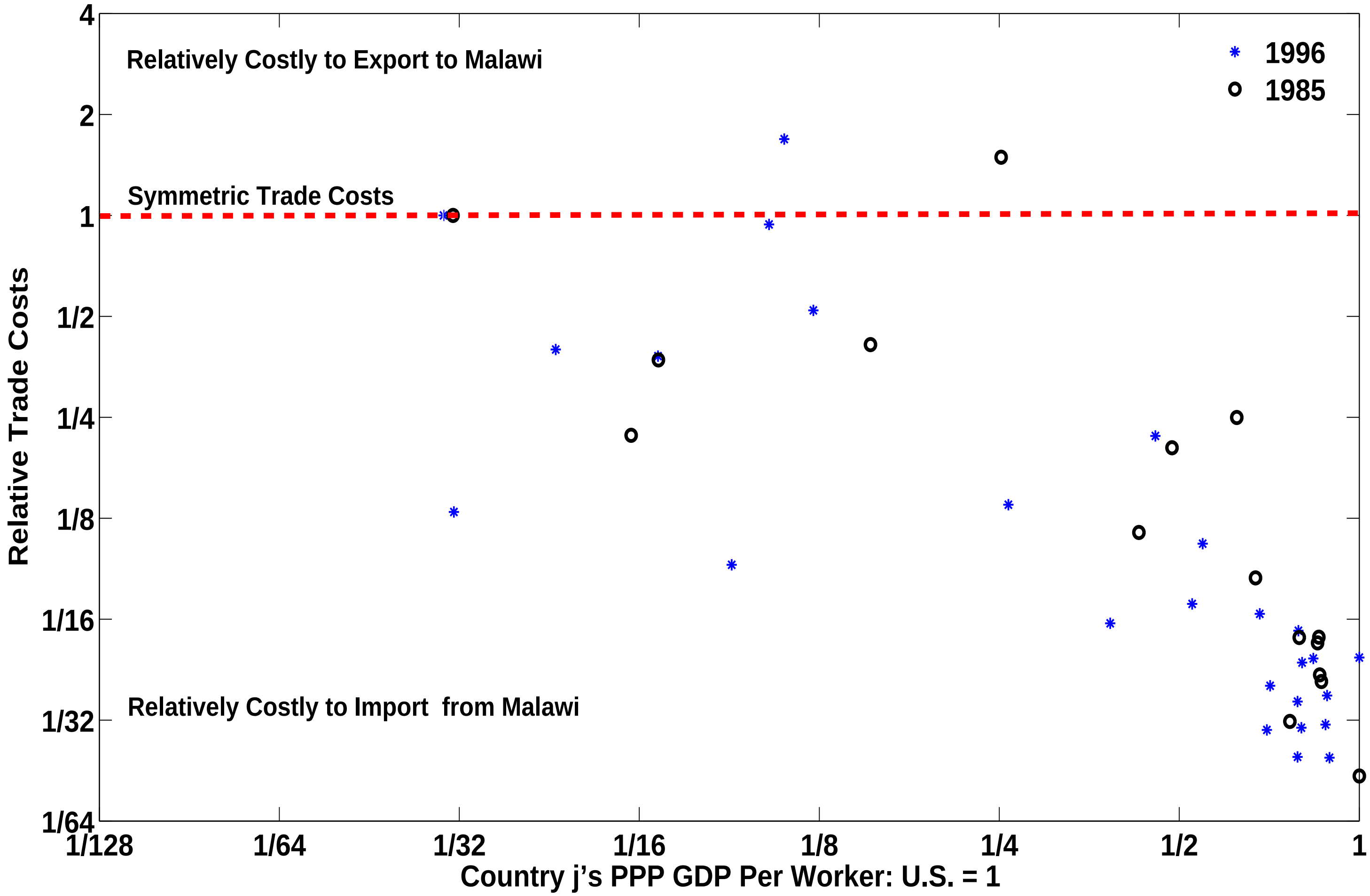

Figure 5: Malawi Relative Trade Cost: $\frac{\tau_{malawi,\ j}}{\tau_{j,\ malawi}}$.

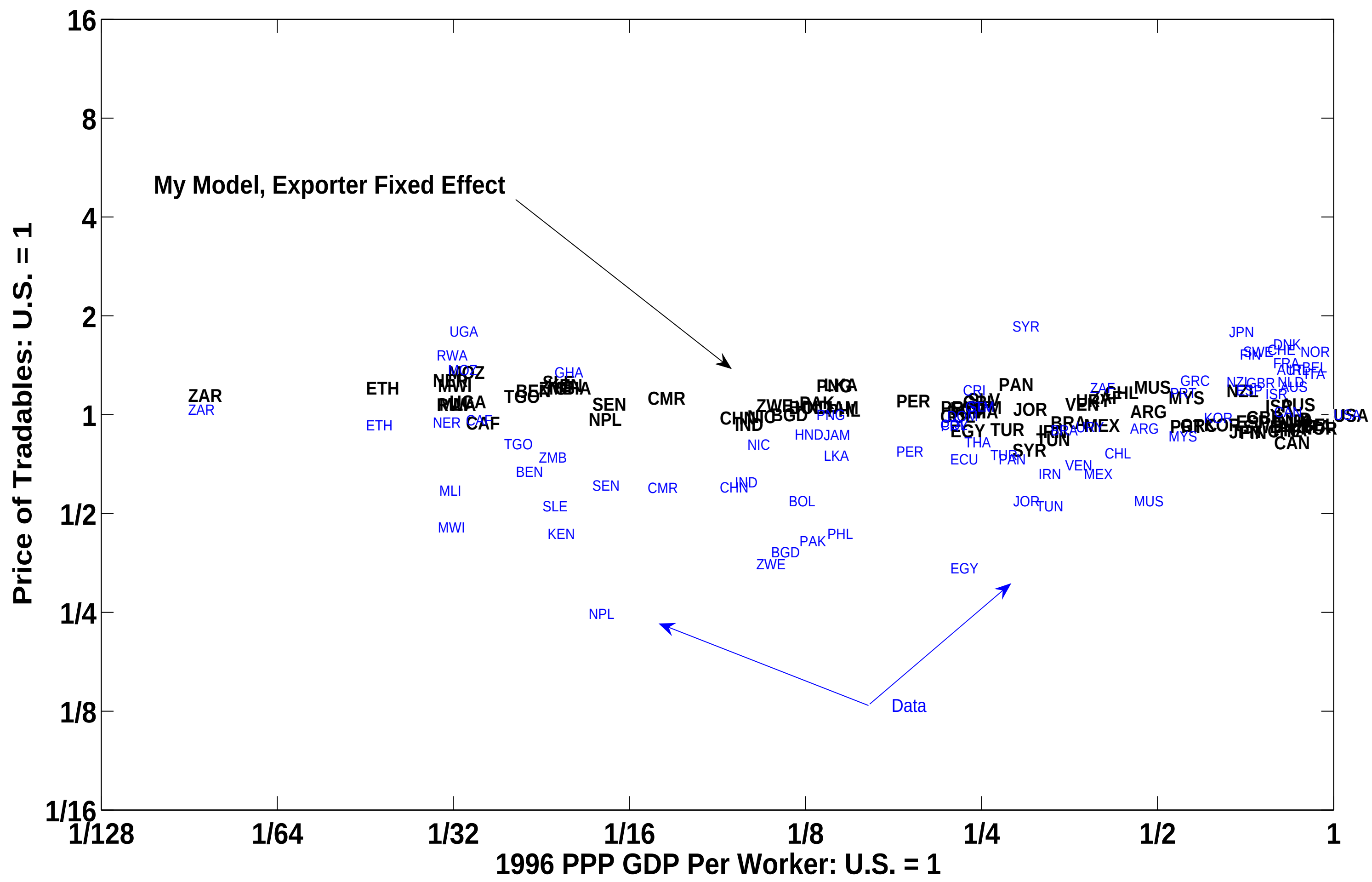

Figure 6: Model Implied Prices Under Alternative Trace Cost Functions

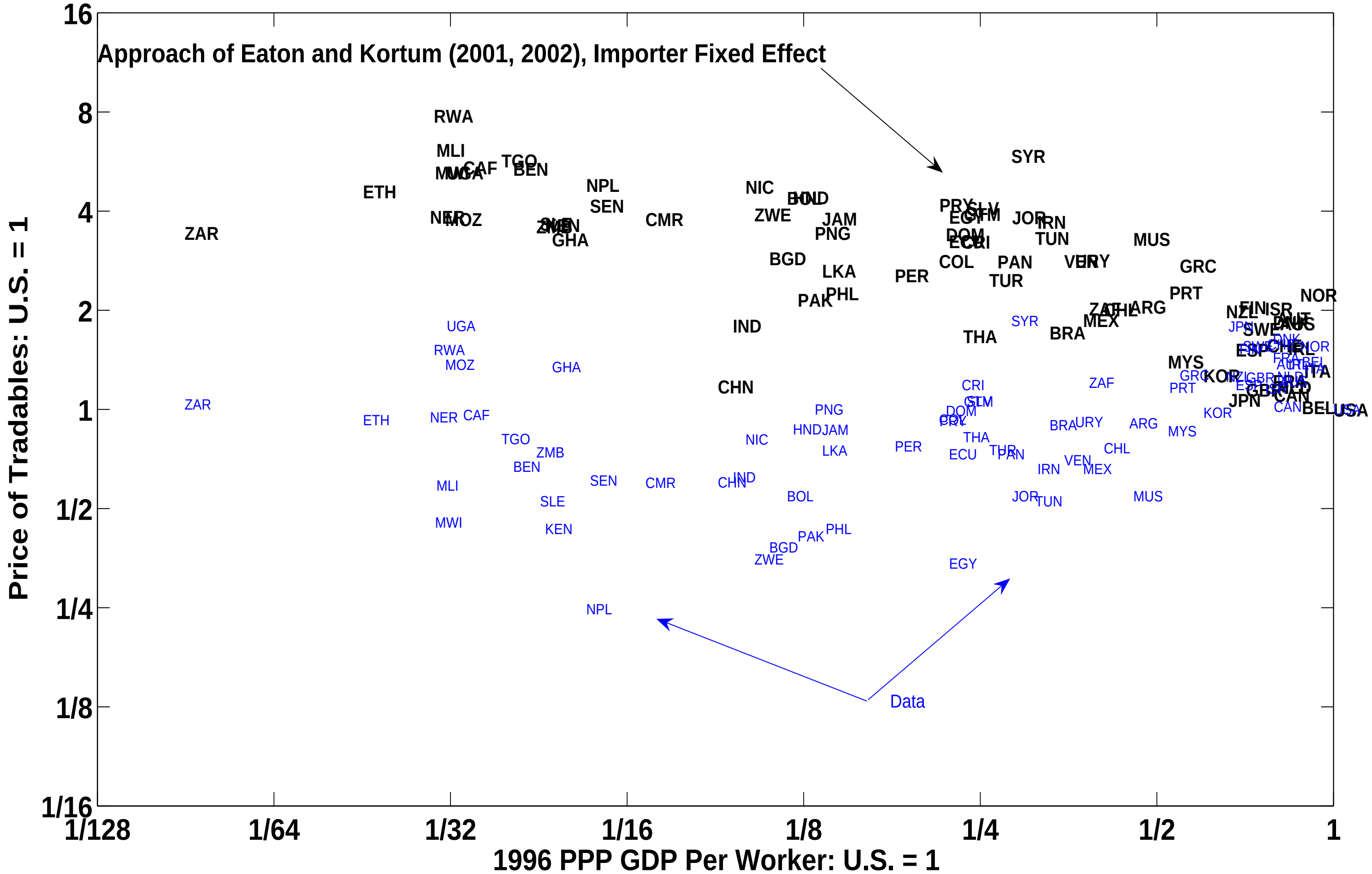

Figure 7: Model Implied Prices Under Alternative Trace Cost Functions

Table 7: Country Price Data

Country	p_i/p_{us} 1985	p_i/p_{us} 1996
United States	1.00	1.00
Argentina	0.62*	0.91
Australia	0.81	1.22
Austria	0.80	1.37
Belgium	0.78	1.39
Benin	0.30	0.67
Bangladesh	0.28	0.38
Bolivia	0.67*	0.55
Brazil	0.52*	0.90
Central African Republic	0.51*	0.96*
Canada	0.98	1.02
Switzerland	0.98*	1.58
Chile	0.56*	0.76
China-Hong Kong	0.39*	0.60*
Cameroon	0.55	0.60
Colombia	0.52*	0.93*
Costa Rica	0.55*	1.19*
Denmark	0.90	1.64
Dominican Republic	0.46*	0.99*
Ecuador	0.77*	0.73
Egypt	0.61	0.34
Spain	0.67	1.19
Ethiopia	0.56	0.93*
Finland	0.97	1.53
France	0.80	1.43
United Kingdom	0.70	1.25
Ghana	0.72*	1.35*
Greece	0.61	1.27
Guatemala	0.71*	1.06*
Honduras	0.71*	0.87*
India	0.49	0.62*
Ireland	0.76	1.37
Iran	0.96	0.66
Israel	0.85*	1.15
Italy	0.66	1.33
Jamaica	0.53	0.87
Jordan	0.91*	0.55
Japan	1.17	1.78
Kenya	0.47	0.43
Republic of Korea	0.69	0.98
Sri Lanka	0.36	0.75*
Mexico	0.58*	0.66
Mali	0.43	0.59
Mozambique	0.67*	1.37*
Mauritius	0.32	0.55

Table 7: Country Data contd.

Country	p_i/p_{us} 1985	p_i/p_{us} 1996
Malawi	0.36	0.45
Malaysia-Singapore	0.63*	0.86*
Niger	0.45*	0.95*
Nicaragua	0.52*	0.81*
Netherlands	0.75	1.26
Norway	1.07	1.56
Nepal	0.36	0.25
New Zealand	0.70	1.26
Pakistan	0.34	0.41
Panama	0.72*	0.73
Peru	0.38*	0.77
Philippines	0.41	0.43
Papua New Guinea	0.43*	1.00*
Portugal	0.61	1.16
Paraguay	0.57*	0.92*
Rwanda	0.51	1.52*
Senegal	0.39	0.61
Sierra Leone	0.54	0.53
El Salvador	0.67*	1.06*
Sweden	1.00	1.56
Syrian Arab Republic	0.86*	1.86
Togo	0.37*	0.81*
Thailand	0.39	0.82
Tunisia	0.48	0.53
Turkey	0.39	0.75
Uganda	0.55*	1.79*
Uruguay	0.50*	0.92
Venezuela	0.80*	0.70
South Africa	0.44*	1.21*
Zaire (DRC)	0.63*	1.04*
Zambia	0.57	0.74
Zimbabwe	0.43	0.35

Note: Column's 2, 3 are constructed as described in section 3. Starred entries denote that the value was imputed as described in section 3. Note, China and Hong Kong and Malaysia and Singapore are aggregated together following Bernard, Eaton, Jensen, and Kortum (2003) to avoid problems with entrepot trade.

Table 8: 1996 Trade Shares X_{ij} in Percent

	U.S.	Can.	Japan	Mexico	China	Senegal	Malawi	Zaire
U.S.	83.25	39.73	2.27	31.62	3.63	2.16	1.57	2.93
Can.	3.78	49.21	0.21	0.72	0.32	0.56	0.67	0.51
Japan	3.04	2.01	92.56	1.59	6.99	1.34	2.65	0.82
Mexico	1.88	1.33	0.02	61.09	0.057	0.01	0	0.007
China	1.78	1.41	1.44	0.30	77.61	2.69	2.50	6.81
Senegal	0*	0*	0*	0	0*	52.68	0	0
Malawi	0*	0*	0*	0	0	0	41.52	0
Zaire	0.003	0.005	0.003	0*	0*	0	0	51.53

Note: Zeros with stars indicate the value is less than 10^{-4}. Zeros without stars are recorded zeros in the data. Entry in row i, column j, is the fraction of goods country j imports from country i.