International Trade and Income Differences

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Abstract

In this paper, I study the relationship between cross-country income differences and international trade in a multi-country general equilibrium model. Using the model, I analytically decompose income per-worker into contributions from capital, productivity, and trade. I show that the contribution from trade is negligible, roughly 4 percent. Nevertheless, after calibrating trade costs and productivity parameters to match bilateral trade flows, I find that the model generates cross-country income differences consistent with the data. I show that reductions in barriers to trade are quantitatively important—they can reduce income differences by up to 56 percent.

Key Words: trade, income, bilateral, total factor productivity, trade costs

JEL Classifications: F0; F1; O4

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1 Introduction

Standards of living between the richest and poorest countries differ by more than a factor of 30. A large literature has evolved attempting to explain this fact within the context of a standard (closed-economy) neoclassical growth model. Beginning with (Mankiw, Romer, and Weil 1992)—and the competing views of (Klenow and Rodriguez-Clare 1997), Hall and Jones (1999), and Parente and Prescott (2002)— the consensus is that physical and human capital accounts for only 50 percent of the variation in income per-worker; the rest is unobserved productivity differences. Given this finding, a growing literature has evolved attempting to understand how differences in economic fundamentals can result in large productivity differences across countries; see Caselli (2005) for a survey.

In most of this literature there is no explicit role for international trade. Yet there are many reasons to think that international trade might be important to understanding cross-country income differences. For example, a majority of all trade is between rich countries, very little is between rich and poor countries. Furthermore, there are many studies documenting the positive correlation between the amount a country trades and its income level; see Frankel and Romer (1999) for example. In policy circles, various anti-globalization movements make claims suggesting rich countries exploit poor countries through trade; see Oxfam International (2002). While international organizations (e.g., The World Bank) emphasize trade as a means of development.

In this paper, I ask and answer the following question: What is the quantitative relationship between international trade and a country's standard of living? To answer this question, I bridge the gap between existing quantitative closed-economy analysis of cross-country income differences and international trade by studying their joint relationship in a quantitative multi-country general equilibrium model. Focusing on the implications of international trade on income, I argue three points: First, given the current volume of trade, trade per-se is not an important factor in explaining cross-country income differences; productivity differences are the driving force. Second, the fundamentals driving the bilateral pattern of trade also drive cross-country income differences. Third, reductions in barriers to trade allow low productivity countries to gain relative to high productivity countries through the *reallocation* of production both within and across countries.

To argue these points, I construct a multi-country model of trade. In each country, there are two sectors: an intermediate goods sector and a final goods sector, both with constant returns technologies. Labor, capital, and intermediate goods are used as factors of production. In the intermediate goods sector there is a continuum of goods. As in Dornbusch, Fischer, and Samuelson (1977), production technologies differ across goods on the continuum only in their efficiency levels.[1] As in Eaton and Kortum (2002), efficiency levels are treated as random variables drawn from a parameterized distribution. Each country's distribution differs in its average efficiency level. Trades only occur within intermediate goods, which are purchased from the country with the lowest price that includes "iceberg" costs to trade. The final goods sector produces a non-traded consumption good with a technology common to all countries.

To quantify the relationship between international trade and a country's income level, I proceed in two ways. First, using the model I derive an accounting procedure that analytically decomposes differences in income per-worker into three components: differences in capital-output ratios, differences in average efficiency, and a contribution from trade. Since the contribution from trade is measurable, this procedure allows me to quantify the extra gain in income per-worker each country receives as a result of trade, circumventing otherwise difficult decisions necessary to calibrate the entire model. Implementing this procedure, I find trade is not quantitatively important in explaining cross-country income differences. In a sample of 77 countries, there is a 26-fold difference in income per-worker between the top 10th percentile and bottom 10th percentile. The contribution from trade is only a factor of 1.13. That is trade's contribution is so small that relative incomes are almost the same in a model with *no* trade.

In most income accounting exercises, this is the end of the story. That is, if a factor contributes little, then it suggests the futility of more careful measurement or further study. With trade, this rationale could not be further from the truth. The reason is that the prior result is only a statement regarding the *observed* volume of trade, i.e. the volume of trade does not co-vary systematically enough to be quantitatively meaningful. It says nothing about why trade does not co-vary enough

[1] A Ricardian model is a natural starting point for several reasons. First, differences in technology are the source of comparative advantage in contrast to Heckscher-Ohlin models which emphasize differences in factor endowments. Given the importance of technology differences relative to endowments in understanding cross-country income differences, a Ricardian model is more suited to the question in this paper. Second, Ricardian models with a continuum of goods have a prominent extensive margin. Hummels and Klenow (2005) and Kehoe and Ruhl (2003) document the quantitative importance of the extensive margin in explaining trade flows and trade liberalizations. "New trade theory" models were designed to explain trade between similar countries and have no extensive margin, hence they seem less appropriate for the question in this paper.

or if it should. Nor is it a statement regarding the gains possible if trade policies or trade costs were changed. In fact, I argue the pattern of trade is distorted and cross-country income differences reflect these distortions. Furthermore, the gains by eliminating these distortions are large.

To argue these points, I proceed in a second direction to quantify the relationship between international trade and a country's income level. I calibrate the model by recovering trade costs and each country's average efficiency level from bilateral trade flows. With the recovered parameters, I compute the model's equilibrium and study the model's implications for cross-country income differences and potential gains from reductions in barriers to trade.

After calibrating the model to match the bilateral pattern of trade, I find that the model generates large differences in income per-worker that are consistent with the data. In the data, the ratio of the top 10th percentile to the bottom 10th percentile in income per-worker is 26. In the model, it is 32. Consistent with the accounting exercise, calibrating the model to match the pattern of bilateral trade implies large differences in average efficiency.

However, this is not the only impediment poor countries face. Consistent with the empirical trade literature (see Anderson and van Wincoop (2004) for a survey), there are significant distortions in the form of trade costs present in the pattern of trade. Since the distribution of income across countries depends on the general equilibrium allocation of production, any distortion to the allocation of production affects cross-country income differences. Thus, changes in trade policies and trade costs provide an avenue for poor countries to gain via comparative advantage.

I illustrate this point through several counterfactual experiments by adjusting trade costs, but fixing the calibrated efficiency levels. In one experiment, trade costs are set so that between two countries they both face the minimum of the calibrated trade costs between them. In this experiment, the ratio of the top 10th percentile to the bottom 10th percentile in income per-worker is reduced from 32 to 21. In a second experiment, all trade costs are eliminated. Here, the ratio of the top 10th percentile to the bottom 10th percentile in income per-worker is reduced to 14. In the two experiments cross-country income differences are reduced by nearly 35 percent with relatively moderate declines in trade costs and by 56 percent with a move to frictionless trade—even in the presence of large under-lying differences in average efficiency. By facilitating an improved allocation of production, trade is quantitatively important for economic development.

As mentioned, these results relate to the income accounting literature. Klenow and Rodriguez-

Clare (1997), Hall and Jones (1999), Parente and Prescott (2002), and Caselli (2005) are examples that find cross-country income differences mostly result from differences in total factor productivity. Extending these exercises to an open economy framework, I derive a relationship decomposing total factor productivity into two components: an exogenous efficiency level and an endogenous and measurable contribution from trade. As noted, I show that the latter is not quantitatively important in explaining cross-country income differences. However, eliminating barriers to trade reallocates production across countries allowing poor countries to close the gap in income.

Most recent empirical studies of the relationship between international trade and a country's standard of living have focused on the statistical relationship between the aggregate volume of trade and income level often finding a moderate positive correlation. These studies have faced two difficulties. The first difficulty is that both trade and income are endogenous. For example, a positive correlation between income level and trade may result from high income countries being more productive, have better policies, etc. not because trade by itself raises income. After constructing instruments to control for endogeneity, a moderate positive relationship often remains; see Frankel and Romer (1999) and more recently Noguera and Siscart (2005). Rodriguez and Rodrik (2001), Hallak and Levinsohn (2004), and others have questioned these findings, mostly criticizing the validity of their instruments, leaving the results inconclusive. The second difficulty is that they are reduced-form studies and hence subject to the Lucas critique. That is the estimated coefficients in these studies only reflect correlations, not policy statements regarding how income or welfare may change given a change in barriers to trade. In a quantitative general equilibrium model, my accounting procedure explicitly accounts for the role of international trade on a county's standard of living while avoiding the statistical difficulties previous studies have faced. Furthermore, with an explicit model and the quantification of its parameters, I am able to ask and answer how cross-country income differences would change with the removal of barriers to trade.

Relative to recent quantitative models of international trade, such as Eaton and Kortum (2002) and Alvarez and Lucas (2005), this paper differers in several ways. First, Eaton and Kortum (2002) and Alvarez and Lucas (2005) are principally concerned with the model's implications for trade—with the former studying the bilateral pattern of trade for OECD countries and the latter studying the model's implications for the aggregate volume of trade in a wide cross-section of countries. In contrast, I am principally concerned with the models implications of international trade for cross-country income differences. In addition, my model includes capital. This feature aids the calibration by adjusting for each country's endowment and provides a straightforward comparison between standard closed economy analysis of cross-country income differences and the open economy analysis I perform.

Another distinction lies in the procedures I use to quantify the model. First, I derive an accounting procedure allowing me to evaluate the quantitative importance of trade, using only observed measures of trade, without having to make difficult decisions that are necessary to quantify the whole model. Second, I use equilibrium conditions in the model and data on bilateral trade shares to recover a country's average efficiency level. In this sense, each country's efficiency level is a result from the observed bilateral pattern of trade—disciplining the approach in this paper. In contrast, Alvarez and Lucas (2005) used data on output to calibrate a country's efficiency level. Similarly, Eaton and Kortum (2002) use data on wages to recover each country's efficiency level.

As in Eaton and Kortum (2002), I estimate a structural relationship between observed bilateral trade shares and trade costs resembling a "gravity equation" which has been a foundation of much work in empirical international trade.[2] Unlike traditional "gravity" with symmetric effects, I allow for asymmetric trade costs. Furthermore, the resulting form of asymmetry is different than used in Eaton and Kortum (2002). In the model, different specifications of trade costs imply fundamentally different quantitative implications for prices and cross-country income differences. Waugh (2006) shows how a similar model calibrated to match prices—with *no* restrictions on the form trade costs take—results in trade costs similar to those recovered here. Furthermore, with my approach the model correctly replicates salient features of observed cross-country income differences.

To summarize, this paper makes three contributions regarding the interaction between international trade and income differences. First, using a general equilibrium model, I show trade plays no quantitative role in explaining cross-country income differences. Second, I show that a disciplined calibration of the model fitting only bilateral trade flows generates large differences in income per-worker that are consistent with the data. Third, I show reductions in barriers to trade can reduce cross-country income differences by significant amounts.

The paper proceeds as follows: Sections 2 and 3 describe the model and an equilibrium. Section 4 derives the accounting exercise and describes the calibration of the full model in addition to the

[2] The appendix details an alternative approach to calibrating the model pursued in prior versions of this paper.

data used. Section 5 presents the results and section 6 concludes.

2 The Model

Consider a world with N countries. Each country has two sectors, an intermediate goods sector and a final goods sector. Only intermediate goods are traded. 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.

2.1 Intermediate Goods Sector

As in Dornbusch, Fischer, and Samuelson (1977) there is a continuum of goods indexed by $x \in [0, 1]$ produced and traded. 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.[3] Across goods x, production technologies differ only in their efficiency level $z_i(x)^{-\theta}$. The parameter θ is common to all countries.

The representative firm's problem in country i is to minimize the cost of supplying $m_i(x)$ by choosing capital, labor, and the aggregate intermediate good, given factor prices, r_i, w_i, and p_i^q. All firms in country i have access to the technology for any good x with the efficiency level $z_i(x)^{-\theta}$. Hence, in equilibrium k_i, n_i, and q_i are allocated so that marginal products are equalized across firms and goods are priced at unit cost.

In each country i, individual intermediate goods are aggregated according to a standard symmetric Dixit-Stiglitz technology producing the aggregate intermediate good with elasticity of substitution $\eta > 0$, specified in the next section.

[3] It is worthwhile to contrast the use of intermediate goods here with the model of Yi (2003) in which there are two stages of production, with individual goods x in the first stage of production are used directly in the second stage of production and then aggregated. It is this mechanism that is important for quantitatively explaining the growth in world trade.

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 (2005) and assume that $z_i(x)$ is distributed independently and exponentially with parameter λ_i across countries. This is analogous to a Type II extreme value distribution or Fréchet distribution as in Eaton and Kortum (2002).

In the production of intermediate 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 $z(x)$, it is taken to the power $-\theta$ and yields 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, the production of the aggregate intermediate good is

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

Where $\pi(z)$ is

$$\pi(z) = \left(\prod_{i=1}^{N} \lambda_i\right) \exp\left(-\sum_{i=1}^{N} \lambda_i z_i\right).$$

In country i, firms producing the aggregate intermediate good face the problem of minimizing the cost of producing q_i. The solution to this problem yields the following price of the aggregate intermediate good:

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

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

2.3 Final Goods Sector

In each country, a representative firm produces a homogenous good which is non-traded. Each firm has access to the following nested Cobb-Douglas production function combining capital, labor, and the aggregate intermediate good:

$$y_i = [k_i^{\alpha} n_i^{1-\alpha}]^{\gamma} q_i^{1-\gamma}.$$

Factor shares, α and γ, are the same across countries.

The representative firm's problem is to minimize the cost of producing y_i, at price p_i^y, by selecting the amount of capital, labor, and aggregate intermediate good, taking prices as given.

2.4 Trade Costs

To model trade costs, the standard iceberg assumption is made, i.e. $\tau_{ij} > 1$ of good z must be shipped from country j for one unit to arrive in country i in which $(\tau_{ij} - 1)$ "melts away" in transit. Trade costs τ_{ij} are thought to be composed of both policy and non-policy related barriers. In addition, τ_{ii} is normalized to equal one for each country, so the proper interpretation of τ_{ij} is the cost of international trade *relative* to internal trade.

3 Equilibrium

The goal is to find allocation rules, prices, and trade shares to construct an equilibrium. Specifically, the functions determining wages, the price of intermediate goods, and trade shares are the most important objects. First, they determine all other equilibrium prices and quantities. Second, these functions provide the basis for the calibration in section 4.

Allocation rules: Allocation rules for capital, labor, and the aggregate intermediate good are easy to compute. Given the production technologies, it is straightforward to show a fraction γ of capital, labor, and the aggregate intermediate good are allocated towards the final goods sector, and a fraction $(1 - \gamma)$ is allocated towards the intermediate goods sector.

Price Index: I show in the appendix that each country faces the following price of intermediate goods for each country i:

$$p_i^q = k_i^{-\alpha\beta}\Upsilon\left\{\sum_{j=1}^{N}\left[w_j^\beta p_j^{q(1-\beta)}\tau_{ij}\right]^{\frac{-1}{\theta}}\left(\frac{k_j}{k_i}\right)^{\frac{\alpha\beta}{\theta}}\lambda_j\right\}^{-\theta} \tag{1}$$

where Υ is a collection of constants. This expression is similar to those in Eaton and Kortum (2002) or Alvarez and Lucas (2005). A difference is in how each country's capital-labor ratio relative to country i "weights" the importance of other countries in the determination of country i's price of intermediate goods. If country j has a relatively larger stock of capital, then its weight on the sum will be higher in contrast to a country with a relatively small stock of capital.

Trade Shares: M_{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. In the appendix, I provide the details which follow the approach in Alvarez and Lucas (2005). The result is the following expression for trade shares:

$$M_{ij} = \frac{\left[k_j^{-\alpha\beta}w_j^\beta p_j^{q(1-\beta)}\tau_{ij}\right]^{\frac{-1}{\theta}}\lambda_j}{\sum_{\ell=1}^{N}\left[k_\ell^{-\alpha\beta}w_\ell^\beta p_\ell^{q(1-\beta)}\tau_{i\ell}\right]^{\frac{-1}{\theta}}\lambda_\ell}. \tag{2}$$

Note that the sum across j for a fixed i must add up to one. Furthermore, with no barriers to trade this relationship is independent of the importer i which implies that all countries purchase the same fraction of goods from the same source.

Wage Function: An equilibrium wage vector is computed given trade shares and imposing balanced trade. Imports are defined as

$$\text{Imports} = L_i p_i^q q_i \sum_{j\neq i}^{N} M_{ij},$$

which is the total value of all goods country i consumes from abroad. Similarly, exports are defined as

$$\text{Exports} = \sum_{j\neq i}^{N} M_{ji} L_j p_j^q q_j,$$

which is the total value of all goods countries abroad purchase from country i.

Imposing balanced trade and including each country i's consumption of goods produced at home implies the following relationship must hold:

$$L_i p_i^q q_i \sum_{j=1}^{N} M_{ij} = \sum_{j=1}^{N} L_j p_j^q q_j M_{ji}.$$

which says the aggregate value of intermediate goods purchased by country i is to equal the value of intermediate goods all N countries purchase from country i.

Using the observation that each country allocates $(1-\gamma)$ of capital and labor to the production of the intermediate goods sector and the relationship between factor payments and total revenue (see Alvarez and Lucas (2005)), the equilibrium wage rate for each country i is:

$$w_i \quad = \quad \sum_{j=1}^{N} \frac{L_j}{L_i} w_j M_{ji}. \tag{3}$$

At this point, the three key pieces of the model have been derived. Equation (1) describes the equilibrium price of intermediate goods, equation (2) describes the fraction of goods countries purchase from each other, and equation (3) describes the equilibrium wage rate for each country. From these functions, all other prices and quantities are determined and an equilibrium constructed.

4 Quantification

To quantify the relationship between international trade and cross-country income differences, I outline two methods.

The first is an accounting exercise analogous to standard income accounting procedures as in Klenow and Rodriguez-Clare (1997) or Hall and Jones (1999). Below, I derive an equilibrium relationship with income decomposed into a contribution from total factor productivity and capital-output ratios. The key feature is that total factor productivity is now endogenous and is an analytical function of how much each country trades. Given data on income per-worker and trade, I can account for the contribution of trade per-se to cross-country income differences.

The second is a calibration/estimation exercise to enable deeper analysis of the model and to allow for counterfactual exercises. Similar to Eaton and Kortum (2002), I derive and estimate a structural relationship between bilateral trade, technology parameters, and trade costs. With the recovered technology parameters and trade costs, I can compute the cross-country income differences implied by the pattern of bilateral trade and study the response of the economy given changes in costs to trade.

In both exercises, the model's trade shares provide a convenient starting point as I can construct an empirical counterpart X_{ij} to the theoretical trade share M_{ij}.

4.1 An Accounting Procedure

Suppressing some notation and rearranging the empirical counterpart of (2) and using (1) provides an expression for each country's home trade share:

$$X_{ii} = \frac{\left[k_i^{-\alpha\beta} w_i^{\beta} p_i^{q(1-\beta)}\right]^{\frac{-1}{\theta}} \lambda_i}{p_i^{q\left(\frac{-1}{\theta}\right)} \Psi}. \tag{4}$$

Further rearrangement of (4) provides the expression:

$$\left(\frac{w_i}{p_i^q}\right) = \Psi \left(\frac{\lambda_i}{X_{ii}}\right)^{\frac{\theta}{\beta}} k_i^{\alpha}, \tag{5}$$

in which wages, deflated by the intermediate goods price, are a function of each country's home trade share and its capital-labor ratio.[4]

I define real income per-worker as:

$$y_i = \frac{w_i}{p_i^y} + \frac{r_i k_i}{p_i^y}, \tag{6}$$

in which income from wages and capital are deflated by each country's final goods price. Then using a representative firm's first order conditions determining the rental rate as a function of the wage, I express income per-worker as a function of only the wage and the final goods price:

$$y_i = \frac{1}{1-\alpha} \frac{w_i}{p_i^y}. \tag{7}$$

[4]For reference, this is analogous to equation (15) in Eaton and Kortum (2002). I have to thank Sam Kortum for directing my attention to this equation.

Since my interest is only in relative income differences, constant terms are abstracted from. Combining the expression for the price of final goods and (7), real income per-worker is expressed as:

$$y_i = \left(\frac{w_i}{p_i^q}\right)^{1-\gamma} k_i^{\alpha\gamma}. \tag{8}$$

Combining equations (5) and (8), real income per-worker is now:

$$y_i = X_{ii}^{\frac{-\theta(1-\gamma)}{\beta}} \lambda_i^{\frac{\theta(1-\gamma)}{\beta}} k_i^{\alpha}. \tag{9}$$

Here real income per-worker is only a function of each countries home trade share X_{ii}, its technology parameter λ_i, and its capital-labor ratio.

Finally, I express income per-worker relative to the U.S. following Hall and Jones (1999) with income decomposed into terms of total factor productivity and capital-output ratios. But here total factor productivity is decomposed into an endogenous trade factor and an exogenous domestic factor:

$$\begin{aligned} \frac{y_i}{y_{us}} &= \left(\frac{A_i}{A_{us}}\right)^{\frac{1}{1-\alpha}} \left(\frac{k_i/y_i}{k_{us}/y_{us}}\right)^{\frac{\alpha}{1-\alpha}}, \\ \frac{A_i}{A_{us}} &= \underbrace{\left(\frac{X_{ii}}{X_{us,us}}\right)^{\frac{-\theta(1-\gamma)}{\beta}}}_{trade-factor} \underbrace{\left(\frac{\lambda_i}{\lambda_{us}}\right)^{\frac{\theta(1-\gamma)}{\beta}}}_{domestic-factor}. \end{aligned} \tag{10}$$

Given this representation, each country's gain from trade, in the form of increased total factor productivity, is $\left(\frac{X_{ii}}{X_{us,us}}\right)^{\frac{-\theta(1-\gamma)}{\beta}}$ and termed the trade factor. Notice that a smaller home trade share for country i implies country i imports a larger fraction of goods from the rest of the world. This expression has several straightforward implications. First, if country i has a smaller home trade share than the U.S., then country i gains relatively more from trade. Second, the higher the share of intermediate goods in either sector results in a larger gain from trade than otherwise. Finally, if the world has a larger θ and hence a higher degree of comparative advantage, then trade will matter more than otherwise. Note as well, only through importing does trade benefit a county. A country's exporting behavior is principally determined by its technology parameter λ and other countries trade costs.

When trade costs are infinite, countries are unable to diversify production and must import everything from home. Hence, $X_{ii} = 1$ and relative income per-worker is then:

$$\frac{y_i^{closed}}{y_{us}^{closed}} = \left(\frac{\lambda_i}{\lambda_{us}}\right)^{\frac{\theta(1-\gamma)}{\beta}} \left(\frac{k_i}{k_{us}}\right)^{\alpha}.$$

Given how efficiency levels are distributed in the production of intermediate goods, each country's average efficiency level relative to the U.S. is $\left(\frac{\lambda_i}{\lambda_{us}}\right)^{\theta}$. Thus, each country's closed-economy total factor productivity is its average efficiency level $\left(\frac{\lambda_i}{\lambda_{us}}\right)^{\theta}$ to the power $\frac{(1-\gamma)}{\beta}$. Hence the second term in brackets in equation (10) is termed the domestic factor.

This accounting procedure is a step forward relative to recent studies concerning the relationship between international trade and a country's standard of living. The principal focus of these studies have been on the statistical relationship between the aggregate volume of trade and income level. These studies face two difficulties. The first difficulty is that both trade and income are endogenous. To avoid this difficulty, Frankel and Romer (1999) and other authors have proposed instruments to correct for these problems. However, as outlined in Rodriguez and Rodrik (2001), there is some debate surrounding the validity of the instruments used leaving the results inconclusive. In contrast to these approaches, the derived accounting relationship in (10)—in conjunction with careful measurement—allow for the quantification of the relationship between trade and income without dealing with these statistical issues.

The second difficulty behind these prior studies is that as reduced-form frameworks they are unable to quantify the response from changes in fundamentals on income and trade. That is the estimated coefficients in these studies only reflect correlations, not statements regarding how income may change in response to changes in barriers to trade. In contrast, this framework can ask and quantitatively answer these questions. To answer them, however, the full model must be quantified which the next section discusses.

4.2 Recovering Trade Costs and Technology

To study how cross-country income differences respond to changes in barriers to trade, I must recover the unknown technology parameters and trade costs. To recover these parameters, I derive and estimate structural equation which resembles a reduced-form "gravity" equation widely used in empirical international trade.[5]

To derive the gravity equation, rearrange the empirical counterpart of (2), using (1) and then for convenience define $c_i = k_i^{\frac{\alpha\beta}{\theta}} w_i^{\frac{-\beta}{\theta}} \lambda_i$, yielding following expression:

$$X_{ii} = \Psi^{-1} c_i p_i^{q\left(\frac{\beta}{\theta}\right)}, \tag{11}$$

$$X_{ij} = \frac{c_j p_j^{q\left(\frac{\beta-1}{\theta}\right)} \tau_{ij}^{\frac{-1}{\theta}}}{p_i^{q\left(\frac{-1}{\theta}\right)} \Psi}, \tag{12}$$

As discussed in Eaton and Kortum (2002), the framework here nests a log-linear "gravity equation" relationship. To derive this, divide each country i's trade share from country j in (12) by country i's home trade share (11) yielding $N-1$ equations for each country i:

$$\left(\frac{X_{ij}}{X_{ii}}\right) = \frac{c_j p_j^{q\left(\frac{\beta-1}{\theta}\right)} \tau_{ij}^{\frac{-1}{\theta}}}{c_i p_i^{q\left(\frac{\beta-1}{\theta}\right)}}. \tag{13}$$

Taking logs yields the following linear relationship ready for estimation:

$$\log\left(\frac{X_{ij}}{X_{ii}}\right) = S_j - S_i - \frac{1}{\theta}\log \tau_{ij}, \tag{14}$$

in which S_i is defined as $\log\left(c_i p_i^{q\left(\frac{\beta-1}{\theta}\right)}\right)$.

To recover the technology parameters and trade costs implied by the pattern of trade, I estimate equation (14) with the S_is recovered as the coefficients on country specific dummy variables. Unfortunately, to recover trade costs, I must assume a technological relationship between τ_{ij} and observable data. I assume trade costs take the functional form:

$$\log(\tau_{ij}) = d_k + b_{ij} + ex_j + \epsilon_{ij}. \tag{15}$$

[5]In previous versions of this paper, I used an alternative approach to calibrate each country's technology level and trade costs by constructing an algorithm to recover the values that fit the trade data in an exact manner. I have deviated from this approach though the appendix provides details. The approach here has the benefit of being dramatically more transparent, easier to replicate, and quantifies the effect of distance—all while yielding essentially the same results.

Here trade costs are a logarithmic function of distance where d_k with $k = 1, 2, ...6$ is the effect of distance between country i and j lying in the kth distance intervals. Intervals are in miles: $[0, 375)$; $[375, 750)$; $[750, 1500)$; $[1500, 3000)$; $[3000, 6000)$; and $[6000, \text{maximum}]$. b_{ij} is the effect of a shared border in which $b_{ij} = 1$, if country i and j share a border, zero otherwise. For estimation purposes, I assume ϵ_{ij} reflects barriers to trade arising from all other factors and is orthogonal to the regressors. These features of the trade cost function are the same as in Eaton and Kortum (2002).

An important difference lies in the term ex_j which is an arrival effect. That is, the estimate of ex_j is the extra cost country j faces to export a good to any country i. Incorporating this term allows for: (i) asymmetry in trade costs and (ii) replicates the pattern of asymmetry observed in Waugh (2006). Waugh (2006) shows how a similar model calibrated to match prices and trade flows—with *no* restrictions on the form trade costs take—results in trade costs that systematically deviate from symmetry with respect to a country's level of development. More specifically, poor countries face systematically higher costs to *export* relative to rich countries. A trade cost function with an arrival effect replicates this observation; see section 5.2 and figure 3.

In contrast, Eaton and Kortum (2002) employ a destination effect m_i in which the estimate m_i reflects the extra cost county i faces to import a good from any country j. When the model is estimated with a destination effect, the resulting prices are inconsistent with data. For example, Eaton and Kortum (2001) estimate the price of investment goods from bilateral trade flows and find that poor countries face higher prices of investment goods relative to rich countries. This result conflicts with the data which shows poor countries face no higher prices for investment goods relative to rich countries; see Hsieh and Klenow (2003) for a discussion. The force driving this result are the trade costs with poor countries facing systematically higher trade costs to *import* relative to rich countries which is induced by estimating the model with a destination effect. Taken together, this suggests employing a destination effect is not empirically supported. Here, I employ an arrival effect because it results in similar trade costs and replicates the pattern of asymmetry observed in Waugh (2006) which is disciplined by data on prices.

Equations (14) and (15) provide the basis for the estimation of trade costs τ_{ij}s and S_is for which I will use ordinary least squares.[6]

[6] I also experimented with the poisson pseudo maximum-likelihood estimator advocated by Silva and Tenreyro

Recovering the λ_is requires more work. Given the estimated S_is and τ_{ij}s, the price of intermediate goods is then computed as:

$$p_i^q = \Upsilon \left\{ \sum_{j=1}^{N} e^{S_j} \tau_{ij}^{\frac{-1}{\theta}} \right\}^{-\theta} \tag{16}$$

Then given the p_i^qs computed from (16), one can recover c_is from the estimates of S_i.

With c_is, more information is required to recover each country's technology parameter λ_i. To recover the λ_is, I determine wages from observed bilateral trade shares X_{ij}, each country's labor endowment, and the empirical counterpart to equation (3):

$$w_i = \left(\sum_{j=1}^{N} \frac{L_j}{L_i} w_j X_{ji} \right). \tag{17}$$

Wages are determined as a function of bilateral trade shares and labor endowments. Then, in combination with aggregate capital-labor ratios, the recovered prices p_i^q, and c_is, each country's technology parameter λ_i is recovered.

Notice the key parameters λ_i and τ_{ij} are being determined primarily as a function of bilateral trade shares—adjusted for endowment differences—providing discipline in recovering these parameters. This in contrast to previous approaches. For example, Alvarez and Lucas (2005) pursue two calibrations and studied the implications of their model for the aggregate volume of trade. Their first calibration assumed that each country's λ_i is proportional to an unobservable endowment L_i. This assumption in combination with balanced trade, output data, and some proxies for trade costs such as average tariff rates allowed them to calibrate each country's λ_i and L_i jointly. Their second calibration built on the former, but incorporated the use of relative price data and dropped the proportionality assumption of λ_i and L_i to identify each separately.

In Eaton and Kortum (2002), they use observed wages. With my focus on income differences, this approach would be problematic. In the structure outlined above, the wage rate used is very important because it induces the recovered λ_is to be higher or lower given that wage rate, holding all else constant; see section 5.2. However, by using the equilibrium wage rates determined from (17) discipline is imposed because, a priori, it is not clear what the correlation structure is between

(2006). The next section and footnote 10 contain a discussion.

the equilibrium wages from (17) and income level—if any.

4.3 Data

To implement the accounting exercise and quantification of the full model, I must take a stand on the world economy and how the model corresponds to actual economies.

The model year is 1996 and table 4 details the countries considered.[7] Beginning with the original sample of countries in Parente and Prescott (1994), some countries were eliminated on the basis of data availability. Thus, 77 countries remain and represent over 90 percent of World GDP.[8]

I assume that the intermediate goods sector corresponds to the manufacturing goods sector. This is a simplification, but since all trade in the model is in intermediate goods and nearly 80 percent of all merchandise trade is in manufactured goods this assumption is reasonable as a first-order approximation to reality. The final goods sector is thought of as the sector producing all final goods and services for each economy.

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 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. In table 4, I present the source for each country's gross manufacturing production data. In table 5, I present trade share's for selected countries.

The distance measures used to estimate trade costs are in miles from capital city in country i to capital city in country j calculated by the great circle method.[9] These measures and border data are from from Centre D'Etudes Prospectives Et D'Informations Internationales (http://www.cpeii.fr).

[7] For the same exact set of countries, I also studied the year 1985. Similar results were obtained.

[8] 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. The data constraint is gross manufacturing production data used to construct bilateral trade shares. Hence other countries were eliminated because the necessary data was unavailable.

[9] The great circle method is a way to calculate the shortest distance between two points along the surface of a sphere.

Table 1: Common Parameter Values

Parameter	Description	Value
α	k's share	1/3
β	k and n's share in int. goods production	0.33
γ	k and n's share in final goods production	0.72
η	elasticity of substitution in aggregator	2.0
θ	variation in efficiency levels	0.15

I used aggregate capital-labor ratios from Caselli (2005). They were constructed using the perpetual inventory method using purchasing power parity adjusted investment rates in Heston, Summers, and Aten (2002). I used labor endowments from Caselli (2005) which are from information in Heston, Summers, and Aten (2002) as well. Each country's labor endowment relative to the U.S. is presented in table 4.

I calibrated parameter values common to all countries as follows. I followed Alvarez and Lucas (2005) in selecting the value for η. Other then satisfying the necessary assumptions detailed in the appendix, this value plays no quantitative role.

Given the model's structure resulting in equation (10), I want α to be consistent with the exercises in the income accounting literature. To do so, 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.

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. For OECD countries in 1996 (http://www.sourceoecd.org), the average value added in the manufacturing goods sector is 0.33. This is consistent with the value employed in Yi (2003).

The parameter γ controls value added in final goods production. Since all trade is assumed to be in manufactured goods, this implies $(1-\gamma)$ corresponds with traded manufacturing goods value added in total output. Manufacturing's value added as a fraction of GDP averaged across all countries in the sample is 0.17 as found in World Development Indicators (http://www.worldbank.org/data). I adjusted this number by the fraction of all trade occurring in manufactured goods. Averaging across the fraction of manufactured goods trade for the sample yields a value of 0.60. Together, this implies traded manufactured goods share in final goods production is 0.28 implying a value for γ of 0.72.

The parameter 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 (2005) 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. In the next sections, I discuss the sensitivity of the results for other parameterizations of θ.

An implication of the Eaton and Kortum (2002) framework 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. For the sample considered there are 5,929 possible trading combinations; 1,610 (27 percent) show no trade at all. This presents both an estimation issue and computational issue. Regarding the former, I will omit any zero observed trade flows from the estimation of equation (14). This has been a standard approach in the empirical trade literature. Silva and Tenreyro (2006) propose a poisson pseudo-maximum-likelihood (PPML) estimator to alleviate any bias from log-linearizing equation (13) in the presence of heteroscedasticity and the omission of zero observed trade flows. I employed their technique including zero observed trade flows and I found the results for cross-country income differences do not differ dramatically relative to using OLS.[10]

Regarding the later, when computing equilibrium prices and counterfactuals I will set trade costs for the instances in which X_{ij} is zero to an arbitrarily large value to approximate what appears to be a trade cost of infinity. In table 1, I summarize the selected parameter values.

[10] This does not contradict their findings. Consistent with their results, I find that OLS exaggerates the distance elasticity suggesting the bias they emphasize is present. For example using PPML, the percent effect on cost are 129, 140, 141, 177, 223, and 263 percent for each distance category. Compared to table 7, shorter distances are more costly and longer distances are less costly relative to OLS. This is consistent with a lower distance elasticity Silva and Tenreyro (2006) find when using PPML relative to OLS. Using PPML, the variance of log income is 1.42, in the baseline model it is 1.43. The 90/10 ratio is 28.4, in the baseline model it is 31.9.

5 Results

As discussed in section 4, two methods are used to quantify the relationship between trade and cross-country income differences. The first is an accounting procedure which is only a statement regarding the observed quantities of trade and their quantitative importance in explaining cross-country income differences. The second is the quantification of the full model and considers how cross-country income differences change as barriers to trade change.

5.1 Does Trade Explain Income Differences?

To answer this question, I use the framework outlined in section 4.1 study trade's contribution to relative income differences. As discussed, I can express income per-worker relative to the U.S. with income decomposed into terms of capital-output ratios, an endogenous trade factor, and an exogenous domestic factor:

$$\begin{aligned}\frac{y_i}{y_{us}} &= \left(\frac{A_i}{A_{us}}\right)^{\frac{1}{1-\alpha}} \left(\frac{k_i/y_i}{k_{us}/y_{us}}\right)^{\frac{\alpha}{1-\alpha}}, \\ \frac{A_i}{A_{us}} &= \underbrace{\left(\frac{X_{ii}}{X_{us,us}}\right)^{\frac{-\theta(1-\gamma)}{\beta}}}_{trade-factor} \underbrace{\left(\frac{\lambda_i}{\lambda_{us}}\right)^{\frac{\theta(1-\gamma)}{\beta}}}_{domestic-factor}.\end{aligned}$$

Figure 1 depicts trade factors versus income per-worker data. If the ordered pairs displayed a positive relationship, then this would imply rich countries have higher incomes relative to poor countries because of trade. As figure 1 illustrates, there is a slight negative relationship. Furthermore, the magnitude of this relationship is small and trade factors contribute little to explaining cross-country income differences. For example, the variance of log trade factors is 0.008 and the ratio of trade factors for the top 10th percentile and bottom 10th percentile in income per-worker is approximately 1. Recall, the data's variance of log income per-worker is 1.38 and the 90/10 ratio of income per-worker is 25.6.

These results imply that cross-country income differences are entirely explained by each country's average efficiency level $\left(\frac{\lambda_i}{\lambda_{us}}\right)^{\theta}$ and differences in capital-output ratios. Since the calibrated factor shares α, β, γ result in $\frac{(1-\gamma)}{\beta(1-\alpha)} > 1$, differences in average efficiency are amplified into differences in income per-worker. For example, the ratio of capital-output ratios to the power $\frac{\alpha}{1-\alpha}$ for the top 10th percentile and bottom 10th percentile in income per-worker is approximately 2. With trade factors contributing next to nothing, this implies the ratio of average efficiency for the top 10th percentile and bottom 10th percentile in income per-worker is approximately 7.6. Taking 7.6 to the power $\frac{(1-\gamma)}{\beta(1-\alpha)}$ results in a factor of approximately 13. These two factors, $13 \times 2 = 26$, accounts for all the variation in income per-worker.

The finding that trade contributes little to explaining cross-country income differences, reflected in figure 1, is insensitive to different values of θ. I performed the same exercise with θ set equal to 0.10 and 0.20 at the low and high end for empirically plausible values. Consistent with the prior results, trade factors showed little variation across income levels. That is, trade plays no quantitative role in explaining cross-country income differences as in the baseline calibration. The reasons are straightforward. Figure 2 plots $\left(\frac{X_{us,us}}{X_{ii}}\right)$ versus income per-worker data. The correlation between income level and this measure of trade is -0.32 and is statistically different from zero. Hence any value of $\theta > 0$ will result in the finding that poor countries seem to gain relatively from trade. Second, though there is substantial variation in $\left(\frac{X_{us,us}}{X_{ii}}\right)$, empirically plausible values for θ are too small and/or countries do not trade enough for trade to have any quantitative meaning.

5.2 Trade Costs, Technology, and Income Differences

The prior result is only a statement regarding the *observed* volume of trade, i.e. the volume of trade does not co-vary systematically enough to be quantitatively meaningful. It says nothing about why trade does not co-vary enough or if it should. Nor is it a statement regarding the gains possible if trade policies or trade costs were changed. To say why trade does co-vary enough or if it should and to asses the gains possible if trade policies or trade costs were changed, I employ the calibration procedure as detailed in section 4.2. That is, I recovered each country's λ_i and trade costs τ_{ij} from pattern of bilateral trade. Table 6 presents summary statistics from the estimation of the structural gravity equation. Tables 7 and 8 present the parameter estimates for trade costs and technology parameters.

Trade Costs: The parameter estimates in table 7 themselves are not of interest here, only the reconstructed trade costs as inputs into the model. However, there are two features to note.

Consistent with the gravity literature, distance is an impediment and the estimates reported are consistent with those in Eaton and Kortum (2001). The overall size of the trade costs for a developed country are consistent with those reported in Anderson and van Wincoop (2004). They survey the literature and report that for a representative developed country, trade barriers fall in a range between 40-80 percent depending on the study and elasticities of substitution. I find that the median trade cost between for OECD countries is equivalent to a 90 percent tariff. This is above the upper-range of their survey, but not dramatically so.

Second, the arrival effect is negatively correlated with income level. Figure 3 plots each country's arrival effect, expressed in terms of the percent effect on cost, versus income per-worker. The correlation between the arrival effect and log income per-worker is -0.66 and statistically different from zero. As the figure depicts, poor countries appear to have a serious disadvantage at exporting goods relative to rich countries. For example, a good arriving from the United States costs 55 percent less than the average country. In contrast, a good arriving from Rwanda will cost 130 percent more than the average country. These results are consistent with Waugh (2006) which shows how a similar model calibrated to match prices and trade flows—with *no* restrictions on the form trade costs take—results in trade costs with poor countries facing systematically higher costs to export relative to rich countries.

Technology: Table 8 presents the parameter estimates for the technology parameters. The key observation here is that differences in average efficiency recovered from the pattern of trade are consistent with the findings from the accounting exercise. For example, the ratio of average efficiency for the top 10th percentile and bottom 10th percentile in λs is approximately 7.96 when estimated from trade data. As mentioned, in the accounting exercise it is 7.58. This an important observation, because two alternative procedures to calibrating λ_i are providing the similar answers suggesting the parameter estimates here are the correct values. Furthermore, the ability of the model to replicate cross-country income differences further reinforces this point as discussed next.

Income Differences: As an assessment of the model, I considered the model's ability to quantitatively replicate the cross-country income differences seen in the data. With the λ_is and τ_{ij}s recovered from the pattern of bilateral trade, I computed an equilibrium and each country's income per-worker as defined in equation (6). Given this definition of income, the natural empirical

Table 2: Income Per-Worker

	var [log(y)]	y_{90}/y_{10}	Gini
Data	1.38	25.6	0.60
Model	1.43	31.9	0.59

analog for comparison is purchasing power parity adjusted income per-worker taken from Heston, Summers, and Aten (2002).

Figure 4 depicts the model's income levels versus the data relative to the U.S. along with the 45° line. If the model's relative income per-worker is the same as the data, then the ordered pairs would map out the 45° line. In figure 4, the ordered pairs lie around the 45° line. For example, the model predicts that Uganda has an income level 1/30 the U.S. level. In the data, Uganda has an income level 1/32 the U.S. level. Table 2 provides some summary statistics: the variance of log income, the 90/10 percentile ratio, and the Gini index.[11] Except for the the Gini index, the summary statistics indicate the model slightly over-predicts the variation in cross-country income differences.

The model predicts incorrectly which countries within the rich are the richest. One potential reason is the absence of Germany. Inclusion of Germany would make European countries look a bit less productive and reduce their income levels relative to the U.S. The model also misses on Zaire (the Democratic Republic of the Congo) by a wide margin. In the data, the U.S. is richer by a factor of 90, in the model it is 19.7. Overall, the model—calibrated to match the bilateral pattern of trade—performs well in capturing the variation in income across countries.

Where does this result arise from? The finding that the model matches the variation in income per-worker when calibrated to match the bilateral pattern of trade arises from several observations. First, the estimated λ_is are the most important object. This is seen the expression for income per-worker in (10). Since the impact of trade is small (and the model's fit of the trade data is tight) and capital stocks are taken from the data, the recovered λ_is are the most important component in determining cross-country income differences.

[11] For the year 1985, results in figure 4 and table 2 are similar. For the model calibrated using 1985 data but the same common parameter values calibrated to 1996 data, the variance of log income is 1.25, in the data it is 1.11. The results in figure 4 and table 2 are also insensitive to different values of 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 a θ of 0.10, the variance of log income is 1.38. For a θ of 0.20 the variance of log income is 1.34. Overall, the model performs well in capturing the variation in income across countries for different years and values of θ.

What drives the variation in λ_is? To answer this question assume for simplicity that the world is only composed of two countries. Take equation (11) and divide the expression for country i by j. With some algebra this provides an expression for relative λs between country i and j:

$$\left(\frac{X_{ii}}{X_{jj}}\right)^{\theta}\left(\frac{k_j}{k_j}\right)^{\alpha\beta}\left(\frac{p_i}{p_j}\right)^{-\beta}\left(\frac{w_i}{w_j}\right)^{\beta}=\left(\frac{\lambda_i}{\lambda_j}\right)^{\theta} \tag{18}$$

Note that the wage and price of intermediate goods are the objects central to determining relative λs. A larger relative wage between country i and j yields a larger relative λ. If country i faces lower a lower price of intermediate goods relative to country j, then this results in a larger relative λ. Furthermore, capital works in the opposite direction adjusting the productivity differences appropriately and the influence of home trade shares is negligible as discussed in section 5.1.

As discussed in section 4.2, wages are an outcome of the equilibrium relationship in equation (17), labor endowments, and the bilateral pattern of trade. Using equation (17), relative wages between the two countries are:

$$\frac{w_i}{w_j}=\frac{L_j}{L_i}\frac{X_{ji}}{X_{ij}}. \tag{19}$$

Then combining (20) and (19) yields:

$$\left(\frac{X_{ii}}{X_{jj}}\right)^{\theta}\left(\frac{L_j}{L_i}\right)^{\beta}\left(\frac{k_j}{k_j}\right)^{\alpha\beta}\left(\frac{p_i}{p_j}\right)^{-\beta}\left(\frac{X_{ji}}{X_{ij}}\right)^{\beta}=\left(\frac{\lambda_i}{\lambda_j}\right)^{\theta} \tag{20}$$

The first bracketed term is the influence of home trade shares and is negligible. The second and third bracketed terms adjust each country's productivity level for endowment differences. The key terms are the fourth and fifth bracketed term.

First, concentrate on the fifth bracketed term which illustrates how bilateral trade shares influence the recovered λs. Holding all else constant, if the fraction of goods country j purchases from country i is larger than the fraction of goods country i purchases from country j, i.e. $X_{ji} > X_{ij}$, then equation (20) says country i must be more productive then country j. To see the influence of this effect, return to table 2 which presents bilateral trade shares for selected countries. In table 5, contrast the upper right quadrant (encompassing poor countries imports from rich countries) with the lower left quadrant of table 5 (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 which maps into large productivity differential as illustrated in equation (20).

The fourth bracketed term accounts for differences in the price of intermediates goods. If poor countries faced higher prices of intermediate goods relative to rich countries, then this would further amplify any productivity difference. Waugh (2006) documents that poor countries have similar or slightly lower price of tradable goods; Hsieh and Klenow (2003) find a similar result looking only at the price of investment goods. The prices here are consistent with these facts resulting in the fourth bracketed term playing no major role. In contrast, if the model were calibrated as in Eaton and Kortum (2001) or Eaton and Kortum (2002) then poor countries would have higher prices relative to rich countries resulting in implausibly large productivity and cross-country income differences.[12] Hence, replicating prices correctly is important to the empirical implications of the model.

A simple example using the U.S. and Kenya illustrates how (20) works and what forces are important. First, ignore the influence of the term $\left(\frac{X_{ii}}{X_{jj}}\right)^{\theta}$. Second, the terms $\left(\frac{k_{ken}}{k_{us}}\right)^{\alpha\beta}\left(\frac{L_{ken}}{L_{us}}\right)^{\beta}$ is a factor of 0.3. The term $\left(\frac{p_i}{p_j}\right)^{-\beta}$ is a factor of 1.07. The final term $\left(\frac{X_{ken,us}}{X_{us,ken}}\right)^{\beta}$ is a factor of 22. These facts imply that the difference in average efficiency, $\left(\frac{\lambda_{us}}{\lambda_{ken}}\right)^{\theta}$ is a factor of 7 which approximates the full calibration result. Note, the large difference in bilateral trade shares drives the large productive differential between the U.S. and Kenya and endowment differences dampen this effect.

As discussed, the intuition for this result arises from the observations about the bilateral pattern of trade in table 5 and their implication in the model. Poor countries purchase a substantial fraction of their goods from rich countries. Rich countries purchase only a small fraction of their goods from poor countries. In the model's equilibrium with balanced trade, these observations imply that rich countries must have higher wages than poor countries which is then mapped into a productivity differential. This finding can be viewed as the dual of Lucas (1990). He asks why is capital allocated across countries such that rich countries have more capital per-worker than poor countries. One answer to his question is that there are differences in efficiency or other complimentary factors to rationalize this observation. The corollary to his question is to ask how is production allocated across countries. The pattern of trade tells us how production is allocated across countries. The

[12] If the trade cost specification used in Eaton and Kortum (2002) were used to calibrate the model, then the model results in poor countries with prices more than 4 times higher than rich countries. This results in a productivity differential in λs of 40 between the top 10th percentile and bottom 10th percentile. Recall that the accounting exercise implies it is 7.6. Furthermore, the variation of log income per-worker is 2.6 and 90/10 percentile ratio is 100. Recall that in the data it is 1.38 and 26.

previous results show that the pattern of trade between rich and poor countries is such that the only way to reconcile it in the model is with large differences in productivity implying large cross-country income differences consistent with the data.

5.3 How Do Trade Costs Influence Cross-Country Income Differences?

As table 7 illustrates, there are significant distortions present in the pattern of trade. Since the distribution of income across countries depends on the general equilibrium allocation of production, any distortion to the allocation of production suggests cross-country income differences reflect these distortions. For example, trade costs may allow production in an industry (good) to exist in a country which otherwise may have been imported. Reducing trade costs shuts down the production of these relatively inefficient industries (goods) and these goods are now imported. As a result, domestic resources are reallocated toward industries (goods) that the country has a comparative advantage increasing output per-worker. Thus, trade costs through the reallocation of production both within and across countries may play an important role for economic development. To quantify these possibilities, I performed two counterfactual exercises modifying trade costs while fixing the estimated efficiency levels and observed capital-labor ratios.

In the first exercise, I adjusted trade costs so the new costs to trade between two countries are $\hat{\tau}_{ij} = \min(\tau_{ij}, \tau_{ji})$. The premise is that costs above this minimum reflect some extra distortion one country faces while the other does not. Hence, the exercise is to remove these additional distortions to trade. With the new trade costs, the variation in log income per-worker declines to 1.18 and the 90/10 percentile ratio of income per-worker is only 21.3. Cross-country income differences decline by up to 33 percent relative to the baseline model. Note that in this exercise trade costs are still large. In this exercise the median trade cost is 142 percent for all countries. This is significantly larger than the value reported in Anderson and van Wincoop (2004) in for a developed country. Table 3 also reports the welfare gains and associated summary statistics.[13] Note, all countries gain—but poor countries gain relatively more than rich countries.

As a more extreme example, consider a world with no trade costs. In this world, the variation in log income per-worker is only 0.87. The 90/10 percentile ratio of income per-worker in this world is only 13.9. Recall, in the baseline model, the variation in log income per-worker is 1.43

[13] Welfare gains are defined as the percentage increase in consumption across the two equilibria.

Table 3: Welfare Gains, Percent Change

	Mean	Max	Min	Corr.	var [log(y)]	y_{90}/y_{10}
$\min(\tau_{ij}, \tau_{ji})$	22.9	70.3 (Mali)	0.56 (Japan)	-0.69	1.18	21.3
$\tau_{ij} = 1$	118.2	267.8 (Rwanda)	16.8 (Belgium)	-0.83	0.87	13.9

and the 90/10 percentile ratio is 31.9. Eliminating all trade costs reduces cross-country income differences by up to 56 percent. Again, table 3 reports the welfare gains showing all countries gain and poor countries gaining relatively more.[14] Ultimately, the gains from a complete elimination of trade costs are hard to comprehend. However, they are a quantitative measure of the magnitude in which trade is distorted.

In all these results the mechanism behind both results is simple comparative advantage. In the model, each country is very efficient in the production of some set of goods. Without trade costs, countries are able to specialize in a smaller set of goods, trading increased quantities, for export to a larger set of countries. For example, in this world, the fraction of goods the U.S. purchases from home is 13 percent relative to 68 percent in the model with trade costs. Poor countries specialize in even smaller sets of goods concentrating their resources in the production of goods which they have a comparative advantage. The end result is lower relative wage differentials between rich and poor countries. For example, in the world with no trade costs, the variance in log wages is almost half of the baseline calibration (8.06 versus 3.85). This reduction in variance is partially offset by changes in the price of final goods. Together, the result is a decrease in cross-country income differences.[15]

Wether a least some fraction of these gains are achievable through policy changes is an open questions. Alvarez and Lucas (2005) used observed average tariff rates and considered the welfare gains from their reduction. Average tariff rates are probably not a good approximation of the policy component of trade costs since tariffs are not the only policy barriers restricting trade and vary a lot across the goods imported and therefore countries; see Anderson and van Wincoop (2004). Non-policy related changes also provide an avenue for their realization with technological improvements

[14]In the two exercises with θ set to 0.20, the variance of log income declines to 1.05 and 0.80 and the average welfare gain is 30 and 136 percent. With θ set to 0.10 the response is smaller. The variance of log income declines to 1.32 and 0.95 and the average welfare gain is 7.78 and 76.9 percent.

[15]These effects can be seen in equation (10) as well. With no trade costs, low productivity countries specialize in a smaller set of goods for export relative to high productivity countries. Furthermore, with no trade costs, all countries purchases the same fraction of goods from each country. This implies that the fraction of goods purchased from home X_{ii} is smaller for low productivity countries relative to high productivity countries resulting in a decrease in cross-country income differences.

in transportation, infrastructure, communication, etc.

One could argue as well that the gains here are an upper bound. Allowing for changes in factors such as capital would enhance the analysis of these gains. Allowing for endogenous capital accumulation and analyzing the welfare gains across steady states is possible and was performed in previous versions of this paper. Depending on the size of the reduction, endogenous capital accumulation increased the welfare gains by 40 to 70 percent. However, incorporating the transition costs is necessary to tell the whole story, yet computational obstacles prevent the telling of it.

Though total factor productivity is endogenous, each country's average efficiency level was treated as invariant to changes in trade costs. In theory, there are a variety of ways that each country's average efficiency level may change in response to reductions in trade costs—either through the diffusion of technology as in Kortum (1997) and Eaton and Kortum (1999), the influence of increased competition on domestic producers as in Parente and Prescott (2002), or industry reallocations as in Melitz (2003). Future quantitative research along these lines will help clarify the most relevant channels through which countries gain from trade. However, the results here suggest large gains are available *only* from the simple reallocation of production via comparative advantage.

6 Conclusion

In a quantitative general equilibrium model of trade, I argued three points. Decomposing income per-worker into components arising from trade, capital, and efficiency, I showed the contribution from trade is not quantitatively important in explaining cross-country income differences. However, by recovering efficiency parameters and trade costs from the pattern of trade, I showed the pattern of trade is consistent with large cross-country income differences. Third, I showed that distortions in the pattern of trade are quantitatively important to understanding cross-country income differences.

As the analysis here suggests, understanding how countries are quantitatively interrelated via trade is an important topic for continued research. First, understanding why poor countries do not take advantage of trade as a solution to their plight is an important question. Second, since the distribution of income depends on the general equilibrium allocation of production, understanding how capital is allocated across countries takes on a new dimension relative to closed-economy models. Understanding capital flows in a multi-country framework is an important topic for future quantitative models of international trade to take on. Finally, the results emphasize the need to understand cross-country differences in productivity. As the analysis here suggests, not only are they important to understanding income differences, but they are an important feature to understanding the pattern of trade.

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7 Appendix A: Derivation of Price Indices and Trade Shares

In this section, I provide some details concerning the derivation of equations which describe the the price index for intermediate goods and the share of goods purchased from each country. The approach followed here largely follows Alvarez and Lucas (2005).

Rewrite the price of each good $p_i(z)$ as:

$$p_i(z)^{\frac{1}{\theta}} = \Omega^{\frac{1}{\theta}} \min_j \left[(r_j^a w_j^b (p^q)_j^c \tau_{ij})^{\frac{1}{\theta}} z_j \right]. \tag{21}$$

Where $a = \alpha\beta$, $b = (1-\alpha)\beta$, and $c = (1-\beta)$. Note the following facts about the exponential distribution:

- if $z \sim \exp(\lambda)$, $\kappa > 0$, $\Rightarrow \kappa z \sim \exp(\frac{\lambda}{\kappa})$.
- if $z = \min(x, y)$, $y \sim \exp(\mu)$ and $x \sim \exp(\xi) \Rightarrow z \sim \exp(\mu + \xi)$.

This implies that each country i faces the following distribution for prices:

$$p_i(z)^{\frac{1}{\theta}} \sim \exp(\mu_i) \tag{22}$$

$$\text{where} \quad \mu_i = \Omega^{\frac{-1}{\theta}} \sum_{j=1}^{N} [r_j^a w_j^b (p_j^q)^c \tau_{ij}]^{\frac{-1}{\theta}} \lambda_j. \tag{23}$$

This implies the price index for the representative country i is

$$(p_i^q)^{1-\eta} = \left\{ \int_0^\infty \mu_i p_i(z)^{(1-\eta)} \exp[-\mu_i p_i(z)^{\frac{1}{\theta}}] dp_i^{\frac{1}{\theta}} \right\}. \tag{24}$$

Employing a change of variables by setting $s = \mu_i p_i(z)^{\frac{1}{\theta}}$, the expression for (24) may be computed as:

$$(p_i^q)^{1-\eta} = \mu_i^{-(1-\eta)\theta} \int_0^\infty s^{\theta(1-\eta)} \exp(-s) ds, \tag{25}$$

where the integral is the gamma function. Expanding what we have is:

$$p_i^q = \Omega S(\theta, \eta)^{\frac{1}{1-\eta}} \left\{ \sum_{j=1}^{N} [r_j^a w_j^b (p_j^q)^c \tau_{ij}]^{\frac{-1}{\theta}} \lambda_j \right\}^{-\theta}, \tag{26}$$

providing a more useful expression for the price index. $S(\theta,\eta)$ is the gamma function evaluated at $[1+\theta(1-\eta)]$. For $S(\theta,\eta)$ to exist, $1 > \theta(\eta-1)$ must hold which is assumed throughout. Finally, to arrive at (1), note that from a representative firm's first order condition the following relationship must hold:

$$r_i = \frac{\alpha}{1-\alpha} w_i k_i^{-1}.$$

This implies the following expression for each countries price of intermediate goods:

$$p_i^q = \Upsilon \left\{ \sum_{j=1}^{N} [k_j^{-\alpha\beta} w_j^{\beta} (p_j^q)^{(1-\beta)} \tau_{ij}]^{\frac{-1}{\theta}} \lambda_j \right\}^{-\theta}, \tag{27}$$

$$\Upsilon = \Omega S(\theta,\eta)^{\frac{1}{1-\eta}} \left(\frac{\alpha}{1-\alpha}\right)^{\alpha\beta}. \tag{28}$$

From here, one can rearrange (27) as found in the paper:

$$p_i^q = k_i^{-\alpha\beta} \Upsilon \left\{ \sum_{j=1}^{N} \left[w_j^{\beta} (p_j^q)^{(1-\beta)} \tau_{ij} \right]^{\frac{-1}{\theta}} \left(\frac{k_j}{k_i}\right)^{\frac{\alpha\beta}{\theta}} \lambda_j \right\}^{-\theta}. \tag{29}$$

To compute the the probability some country j is the low cost supplier for some good to country i, just a couple more facts about the exponential distribution and order statistics are required:

- if z and y are independent and $z \sim \exp(\xi)$, $y \sim \exp(\mu)$, $\Rightarrow \text{prob}\{z \leq y\} = \frac{\xi}{\mu+\xi}$.

Then note the following observation that

$$\text{Prob}\left\{ p_j(z) \leq \min_{j\neq s}[p_s(z)] \right\} = \text{Prob}\left\{ p_j(z)^{\frac{1}{\theta}} \leq \min_{j\neq s}[p_s(z)^{\frac{1}{\theta}}] \right\}, \tag{30}$$

then denoting M_{ij} as the probability country j is the low cost supplier to country i, one may express M_{ij} as:

$$M_{ij} = \frac{\left[k_j^{-\alpha\beta} w_j^{\beta} (p_j^q)^{(1-\beta)} \tau_{ij}\right]^{\frac{-1}{\theta}} \lambda_j}{\sum_{\ell=1}^{N} \left[k_\ell^{-\alpha\beta} w_\ell^{\beta} (p_\ell^q)^{(1-\beta)} \tau_{i\ell}\right]^{\frac{-1}{\theta}} \lambda_\ell}. \tag{31}$$

8 Appendix B: Calibrating Technology and Trade Costs

In previous versions of this paper, I recovered each country's technology parameter and trade costs in a different manner than described in this version. Specifically, I constructed and implemented an algorithm to select each country's technology parameter and trade costs for every country pair with the goal of avoiding restrictions traditional estimation procedure imposes. That is provide a method that lets the trade data speak for itself. Below, I describe the algorithm and then discusses issues and how the results compare with those in the paper.

8.1 Algorithm

The model's trade shares provide a convenient starting point providing a mapping from observed trade shares to each country's technology parameter λ_i and trade costs τ_{ij} .

To illustrate this mapping, I first determine wages from observed bilateral trade shares X_{ij}, each country's labor endowment, and the empirical counterpart to equation (3):

$$w_i \quad = \quad \left(\sum_{j=1}^{N} \frac{L_j}{L_i} w_j X_{ji} \right) \quad \text{or} \quad g(w; \mathbf{X}) = w, \tag{32}$$

in which expression (32) is written parsimoniously as a fixed-point problem conditioned on the observed bilateral trade share matrix denoted as $\mathbf{X}$. Wages, in combination with aggregate capital to labor ratios, pin down each country's cost structure.

The remaining unknown parameters are N λ_is and $(N^2 - N)$ τ_{ij}s (since $\tau_{ii} = 1$) that yield N^2 trade shares from the model consistent with the data, X_{ij}. With a large number of countries, this seems to be a daunting task requiring a solution to a system of N^2 non-linear equations for N^2 unknowns. However, with some manipulation of (2), this reduces to solving a large fixed-point problem.

Re-arranging the empirical counterpart of (2) and using (1) yields:

$$X_{ii} \quad = \quad \frac{\left[k_i^{-\alpha\beta} w_i(\mathbf{X})^{\beta} p_i^q(\lambda, \tau; \mathbf{X}, k)^{(1-\beta)} \right]^{\frac{-1}{\theta}} \lambda_i}{p_i^q(\lambda, \tau; \mathbf{X}, k)^{\frac{-1}{\theta}} \Psi}, \tag{33}$$

$$X_{ij} = \frac{\left[k_j^{-\alpha\beta} w_j(\mathbf{X})^{\beta} p_j^q(\lambda,\tau;\mathbf{X},k)^{(1-\beta)}\tau_{ij}\right]^{\frac{-1}{\theta}}\lambda_j}{p_i^q(\lambda,\tau;\mathbf{X},k)^{\frac{-1}{\theta}}\Psi}, \tag{34}$$

in which wages, w_i, depend only on $\mathbf{X}$ and p_i^q's dependence on λ, τ, given $\mathbf{X}$ and k is noted. Ψ is a collection of constants. Further manipulation of (33) and (34) yields the following system of equations:

$$X_{ii}\left[\frac{k_i^{-\alpha} w_i(\mathbf{X})}{p_i^q(\lambda,\tau;\mathbf{X},k)}\right]^{\frac{\beta}{\theta}}\Psi = \lambda_i, \quad \forall i = 1...N, \tag{35}$$

$$X_{ij}^{-\theta}\left[\frac{k_j^{-\alpha\beta} w_j(\mathbf{X})^{\beta} p_j^q(\lambda,\tau;\mathbf{X},k)^{1-\beta}}{p_i^q(\lambda,\tau;\mathbf{X},k)}\right]^{-1}\Psi^{-\theta}\lambda_j^{\theta} = \tau_{ij}, \quad \forall i,j; j \neq i. \tag{36}$$

The system expressed as a fixed-point problem is:

$$f(\lambda,\tau;\mathbf{X},k) = \lambda, \tag{37}$$

$$h(\lambda,\tau;\mathbf{X},k) = \tau. \tag{38}$$

The model presented in section 2 is now expressed as a mapping from the pattern of trade to a country's technology parameter and trade costs. Specifically, with data on bilateral trade shares and labor endowments, I compute an equilibrium wage vector from (32). Then, with aggregate capital to labor ratios, trade shares, and parameters common to all countries, I compute each country's technology level λ_i and trade costs τ_{ij}s by the fixed-point problem implied by (37) and (38).

8.2 Issues and Results Comparisons

As pointed out to me by Sam Kortum, the principal issue with the algorithm outlined above is that the solution it generates it not unique. That is there are other combinations of λ_i and τ_{ij} which can rationalize the bilateral trade data. Hence, all that can be said from these results is that these are the parameters contingent on the algorithm. Other algorithms and other approaches might generate results that fit the bilateral trade data equally well.

However, there are ways to evaluate the parameters the algorithm generates or alternative approaches. First note, that trade costs and λ_is are jointly determined in the algorithm just described and the approach used in the paper. Hence the method used to recover trade costs will influence the resulting λ_is. However, recovering λ_is using equation (10)—which relies on no restrictions or assumptions on trade costs—provides a basis for the comparison between alternative approaches. Furthermore, equation (10) makes clear that differences in λ_is result in different implications for cross-country income differences in the model. Hence, if the estimation technique generates cross-country income differences consistent with the data, then one can conclude that these parameters are reasonable.

In previous versions of this paper, the model was generating cross-county income differences consistent with the data. For example, the variance in log income from the model is 1.16 and the 95/5 percentile ratio 30. In the data, the variance of log income is 1.38 and the 95/5 percentile ratio is 30 as well. On this basis, one can say that the algorithm is generating reasonable parameters. Ultimately, both the method in the paper and the algorithm here generate similar results. Both replicate cross-country income differences and generate similar impacts from reductions in barriers to trade on cross-country income differences.

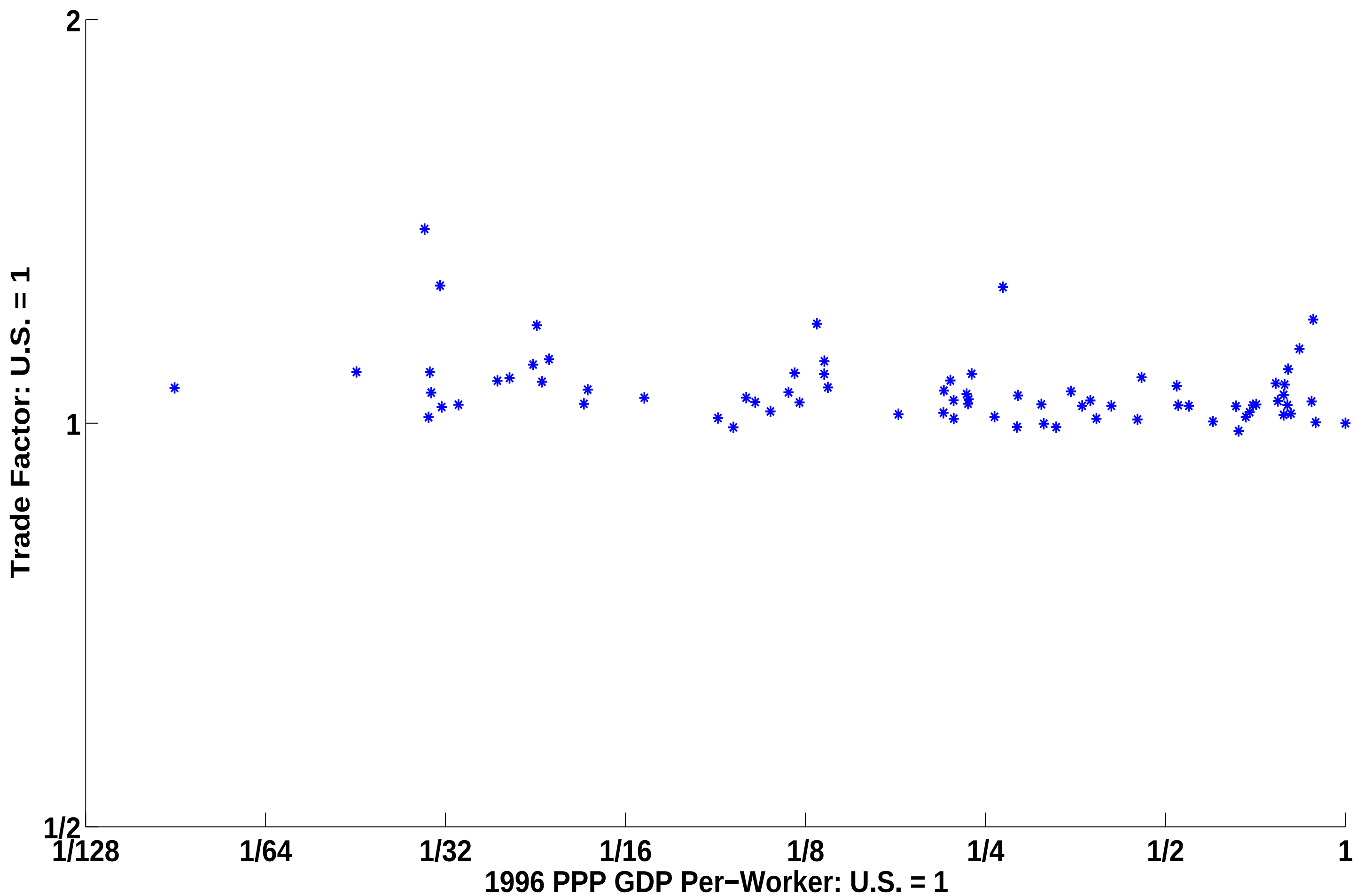

Figure 1: Trade Factors versus Income Data

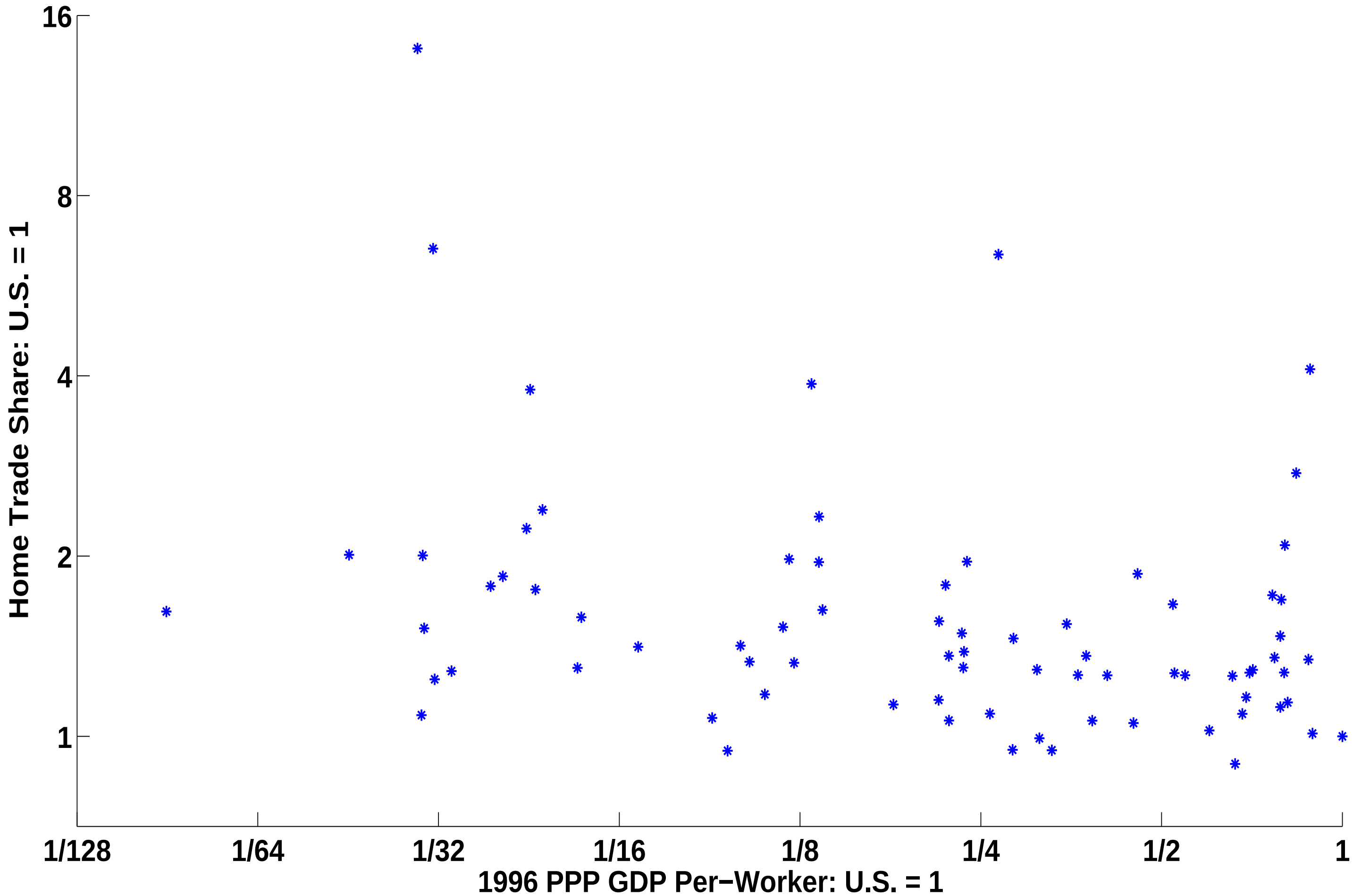

Figure 2: Home Trade Shares versus Income Data

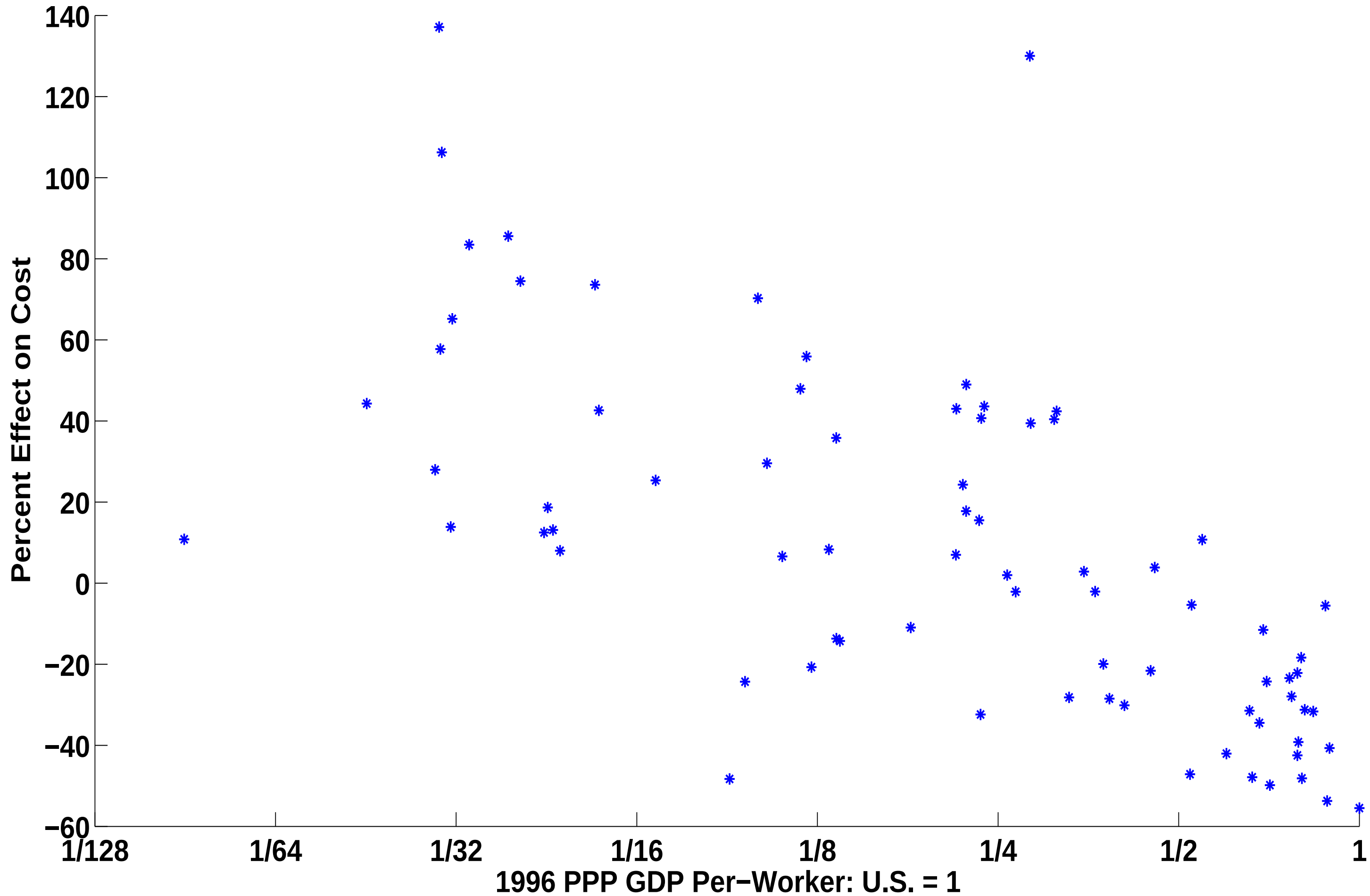

Figure 3: Arrival Effect, Percent Effect on Cost

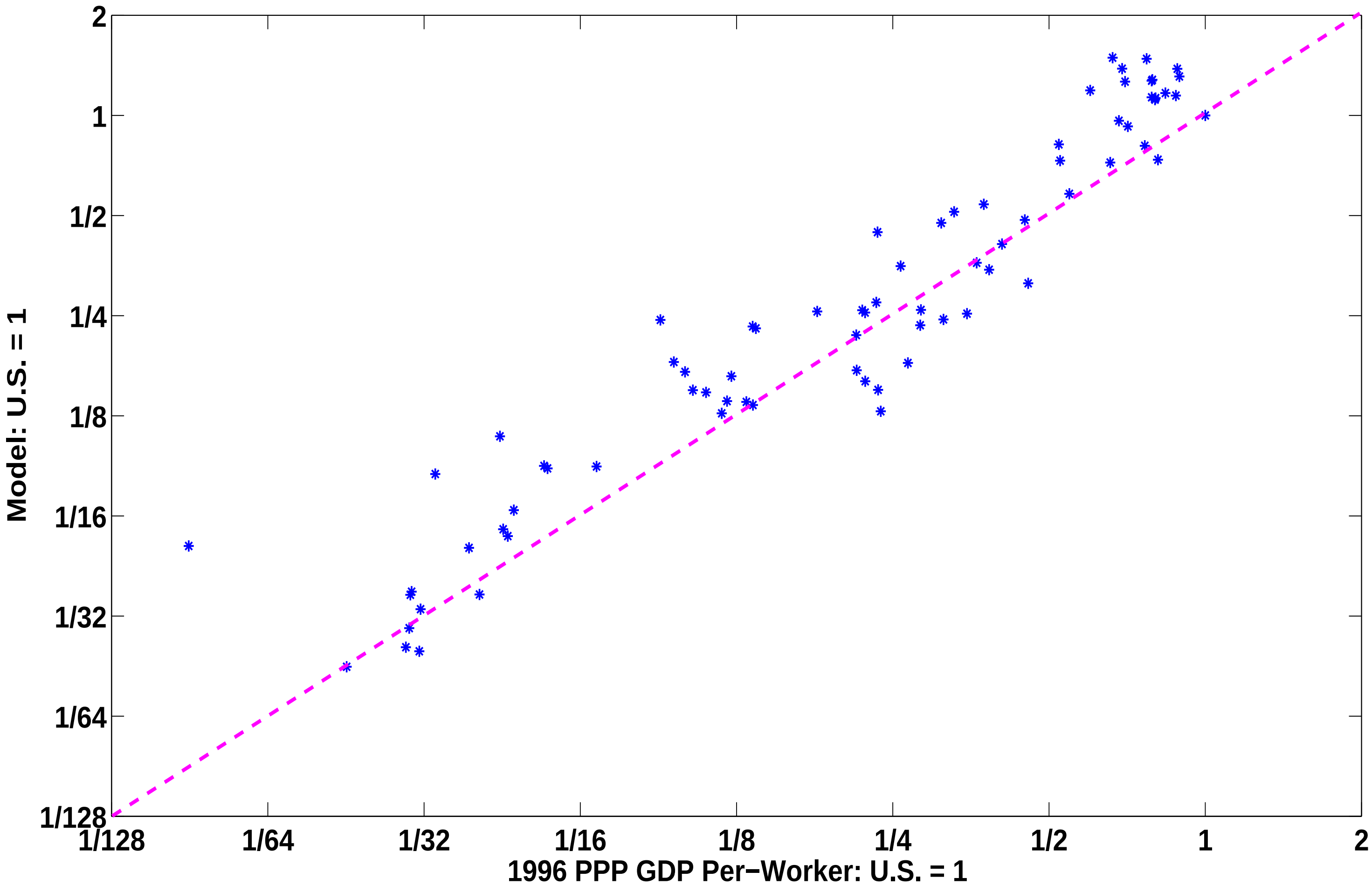

Figure 4: Income: Data and Model

Table 4: Country Data

Country	$\frac{y_{us}}{y_i}$	$\frac{L_{us}}{L_i}$	k_i/y_i	$\frac{X_{ii}}{X_{us,us}}$	Data Source
United States	1.00	1.00	2.19	1.00	O
Argentina	2.23	9.25	1.91	0.95	I
Australia	1.23	15.0	2.56	0.88	O
Austria	1.25	35.8	2.96	0.78	O
Belgium	1.13	31.9	2.80	0.24	O
Benin	25.0	49.6	0.76	0.54	W
Bangladesh	9.15	4.61	0.97	0.85	I
Bolivia	8.54	45.2	1.06	0.66	I
Brazil	3.05	2.28	2.05	1.06	I
Central African Republic	30.4	84.6	0.93	0.78	W
Canada	1.26	8.94	2.70	0.59	O
Switzerland	1.30	34.5	3.59	0.74	I
Chile	2.46	24.3	1.58	0.79	I
China-Hong Kong	11.2	0.18	1.54	0.93	I
Cameroon	14.9	20.2	0.98	0.71	I
Colombia	4.70	7.58	1.25	0.87	I
Costa Rica	4.30	102	1.74	0.67	O
Denmark	1.27	48.1	2.71	0.68	W
Dominican Republic	4.58	54.0	1.29	0.56	I
Ecuador	4.52	37.8	1.99	0.73	W
Egypt	4.52	7.80	0.63	0.94	I
Spain	1.47	8.65	2.83	0.92	I
Ethiopia	45.1	5.34	0.48	0.50	O
Finland	1.45	53.5	3.13	0.86	O
France	1.27	5.06	2.99	0.89	W
United Kingdom	1.41	4.64	2.16	0.77	O
Ghana	21.5	16.0	0.79	0.42	I
Greece	1.83	31.7	2.81	0.79	W
Guatemala	4.27	46.1	0.83	0.72	I
Honduras	8.34	75.2	1.46	0.51	O
India	10.6	0.37	1.04	1.06	I
Ireland	1.19	96.6	1.77	0.36	I
Iran	3.19	7.58	1.85	1.01	O
Israel	1.31	63.1	2.49	0.58	W
Italy	1.12	5.87	2.72	0.99	I
Jamaica	7.44	108	2.31	0.51	O
Jordan	3.53	135	1.59	0.69	I
Japan	1.51	1.69	3.51	1.11	O
Kenya	22.7	9.85	0.96	0.57	I
Republic of Korea	1.67	7.11	2.86	0.98	O
Sri Lanka	7.44	17.7	1.14	0.43	W
Mexico	2.67	4.26	2.06	0.73	I
Mali	33.8	28.2	0.92	0.66	I
Mozambique	32.7	17.1	0.39	0.15	I
Mauritius	2.19	263	1.14	0.54	I

Table 4: Country Data contd.

Country	$\frac{y_{us}}{y_i}$	$\frac{L_{us}}{L_i}$	k_i/y_i	$\frac{X_{ii}}{X_{us,us}}$	Data Source
Malawi	34.0	31.6	1.06	0.50	I
Malaysia-Singapore	1.91	18.2	2.38	0.60	W
Niger	34.7	29.5	0.86	0.07	O
Nicaragua	10.0	95.4	1.72	0.71	O
Netherlands	1.25	18.6	2.66	0.48	W
Norway	1.14	62.2	3.22	0.74	O
Nepal	18.8	14.8	1.43	0.77	I
New Zealand	1.52	77.1	2.55	0.79	I
Pakistan	8.19	3.86	1.07	0.75	I
Panama	3.74	136	2.05	0.16	I
Peru	5.59	13.0	2.24	0.88	W
Philippines	7.34	4.69	1.66	0.62	O
Papua New Guinea	7.66	65.0	1.20	0.26	W
Portugal	1.90	30.2	2.36	0.78	W
Paraguay	4.69	62.2	1.18	0.64	I
Rwanda	34.2	40.9	0.62	0.92	W
Senegal	18.5	33.1	0.80	0.63	O
Sierra Leone	22.5	80.5	0.53	0.26	O
El Salvador	4.22	74.6	0.85	0.51	O
Sweden	1.43	29.4	2.73	0.78	I
Syrian Arab Republic	3.54	37.9	1.05	1.05	W
Togo	26.2	78.8	0.96	0.56	I
Thailand	4.28	4.25	2.78	0.77	I
Tunisia	3.23	45.2	1.45	0.77	I
Turkey	3.86	4.96	1.71	0.92	W
Uganda	32.5	14.1	0.24	0.80	O
Uruguay	2.76	93.2	1.42	0.79	I
Venezuela	2.88	17.4	1.94	0.65	I
South Africa	2.61	10.0	1.27	0.94	I
Zaire (DRC)	90.9	6.08	1.07	0.62	W
Zambia	22.8	43.8	1.93	0.45	W
Zimbabwe	9.71	24.8	1.82	0.75	W

Note: Column's 2, 3, and 4 are constructed from Heston, Summers, and Aten (2002) describing relative income per-worker, relative labor endowments, and each country's capital-output ratio. Column 5 is the relative home trade share for each country—the inverse is depicted in log base 2 scale in figure 2. Column 5 denotes the source of gross manufacturing production data. "O" denotes the OECD. "I" denotes data from the International Yearbook of Industrial Statistics from various years published by the United Nations Industrial Development Organization. "W" denotes the World Bank and gross manufacturing production is computed from value added. 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 5: 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.

Table 6: Summary Statistics

No. Obs	TSS	SSR	σ_ϵ^2
4242	4924	851	2.08

Table 7: Geographic Barriers, $\theta = 0.15$

Barrier	Parameter Estimate	S.E.	%effect on cost
$[0, 375)$	-4.66	0.21	101.1
$[375, 750)$	-5.60	0.13	131.9
$[750, 1500)$	-6.16	0.08	151.9
$[1500, 3000)$	-7.22	0.06	195.2
$[3000, 6000)$	-8.44	0.04	254.8
$[6000, \text{maximum}]$	-9.37	0.04	308.1
Shared Border	0.69	0.16	-10.8
Arrival Country			
United States	5.40	0.23	-55.5
Argentina	1.62	0.25	-22.0
Australia	2.50	0.24	-31.2
Austria	1.35	0.24	-18.4
Belgium	5.13	0.23	-53.7
Benin	-3.71	0.39	74.5
Bangladesh	-0.43	0.26	6.58
Bolivia	-2.61	0.30	47.9
Brazil	2.21	0.25	-28.2
Central African Republic	-4.04	0.50	83.4
Canada	3.32	0.24	-39.2
Switzerland	2.19	0.24	-28.0
Chile	2.40	0.25	-30.1
China-Hong Kong	4.40	0.24	-48.3
Cameroon	-1.50	0.30	25.3
Colombia	-0.45	0.26	6.97
Costa Rica	-0.96	0.29	15.5
Denmark	1.67	0.23	-22.1
Dominican Republic	-1.45	0.28	24.3
Ecuador	-1.09	0.29	17.7
Egypt	-2.66	0.27	48.9
Spain	2.82	0.24	-34.5
Ethiopia	-2.45	0.32	44.3
Finland	0.82	0.24	-11.5
France	3.69	0.24	-42.5
United Kingdom	4.60	0.23	-49.8
Ghana	-0.51	0.33	8.00
Greece	-0.68	0.24	10.7
Guatemala	-2.28	0.29	40.7
Honduras	-2.96	0.33	55.8
India	1.86	0.24	-24.3

Table 7 Contd.

Arrival Country	Parameter Estimate	S.E.	% effect on cost
Ireland	2.54	0.24	−31.7
Iran	−2.35	0.32	42.3
Israel	1.78	0.26	−23.4
Italy	3.48	0.24	−40.7
Jamaica	−2.04	0.31	35.8
Jordan	−2.22	0.32	39.4
Japan	4.35	0.23	−47.9
Kenya	−0.82	0.26	13.1
Republic of Korea	3.64	0.24	−42.0
Sri Lanka	0.98	0.30	−13.7
Mexico	1.49	0.25	−20.0
Mali	−4.83	0.37	106
Mozambique	−0.87	0.36	13.9
Mauritius	−0.26	0.28	3.84
Malawi	−3.04	0.36	57.7
Malaysia-Singapore	4.25	0.24	−47.1
Niger	−1.64	0.38	27.9
Nicaragua	−3.55	0.33	70.2
Netherlands	4.38	0.23	−48.1
Norway	0.38	0.24	−5.55
Nepal	−3.68	0.34	73.6
New Zealand	2.52	0.26	−31.5
Pakistan	1.55	0.23	−20.7
Panama	0.14	0.30	−2.11
Peru	0.77	0.28	−11.0
Philippines	1.03	0.26	−14.3
Papua New Guinea	−0.53	0.37	8.30
Portugal	0.37	0.24	−5.38
Paraguay	−2.38	0.30	43.0
Rwanda	−5.76	0.42	137
Senegal	−2.37	0.33	42.6
Sierra Leone	−1.14	0.38	18.6
El Salvador	−2.41	0.31	43.6
Sweden	1.86	0.24	−24.3
Syrian Arab Republic	−5.55	0.30	130
Togo	−4.12	0.35	86.5
Thailand	2.61	0.26	−32.4
Tunisia	−2.26	0.28	40.4
Turkey	−0.13	0.25	1.98
Uganda	−3.35	0.35	65.2
Uruguay	0.14	0.28	−2.07
Venezuela	−0.19	0.28	2.82
South Africa	2.24	0.25	−28.5
Zaire (DRC)	−0.68	0.33	10.8
Zambia	−0.79	0.34	12.5
Zimbabwe	−1.73	0.28	29.5

Note: The parameters were estimated by OLS. For an estimated parameter $\hat{b}$, the implied percentage effect on cost is $100 \times (e^{\theta\hat{b}} - 1)$.

Table 8: Technology, λ_i

Country	$\hat{S}_i$	S.E.	$\left(\frac{\lambda_{us}}{\lambda_i}\right)^{\theta}$
United States	0.54	0.17	1.00
Argentina	0.69	0.18	1.61
Australia	0.11	0.18	1.38
Austria	0.77	0.17	0.95
Belgium	-1.55	0.17	1.15
Benin	-0.25	0.22	9.98
Bangladesh	0.54	0.21	2.91
Bolivia	-0.09	0.20	3.71
Brazil	1.27	0.18	1.34
Central African Republic	0.33	0.24	3.40
Canada	0.11	0.16	1.00
Switzerland	0.75	0.17	0.77
Chile	-0.39	0.17	1.79
China-Hong Kong	0.76	0.17	1.88
Cameroon	-0.43	0.20	4.52
Colombia	0.63	0.20	2.62
Costa Rica	0.01	0.20	2.44
Denmark	0.81	0.17	0.90
Dominican Republic	-0.49	0.20	2.18
Ecuador	0.06	0.19	2.69
Egypt	1.17	0.18	2.93
Spain	0.53	0.16	1.03
Ethiopia	-1.15	0.22	11.74
Finland	1.39	0.16	0.67
France	0.68	0.16	0.85
United Kingdom	-0.08	0.17	1.10
Ghana	-1.50	0.22	5.47
Greece	0.75	0.17	1.68
Guatemala	-0.03	0.19	3.72
Honduras	-0.46	0.19	3.88
India	1.24	0.18	2.17
Ireland	-0.33	0.17	0.88
Iran	1.20	0.23	3.07
Israel	-0.01	0.20	1.26
Italy	0.85	0.16	0.77
Jamaica	-0.50	0.19	2.63
Jordan	-0.01	0.22	2.74
Japan	1.44	0.17	0.62
Kenya	-0.58	0.18	6.91
Republic of Korea	1.00	0.17	0.78
Sri Lanka	-1.48	0.22	4.03
Mexico	0.76	0.17	1.36
Mali	0.08	0.23	8.93
Mozambique	-2.32	0.23	12.01
Mauritius	-1.04	0.20	2.28

Table 8: **Technology, λ_i contd.**

Country	$\hat{S}_i$	S.E.	$\left(\frac{\lambda_{us}}{\lambda_i}\right)^{\theta}$
Malawi	-0.71	0.23	9.75
Malaysia-Singapore	-0.33	0.17	1.05
Niger	-2.94	0.23	18.43
Nicaragua	0.09	0.20	2.96
Netherlands	-0.75	0.17	1.14
Norway	0.92	0.17	0.96
Nepal	0.62	0.23	4.69
New Zealand	-0.27	0.19	1.33
Pakistan	-0.01	0.18	2.94
Panama	-1.71	0.20	5.58
Peru	-0.08	0.20	2.53
Philippines	-0.12	0.18	2.36
Papua New Guinea	-1.51	0.24	3.80
Portugal	0.61	0.18	1.18
Paraguay	0.26	0.20	3.48
Rwanda	0.24	0.24	9.96
Senegal	-0.36	0.22	3.87
Sierra Leone	-2.01	0.25	5.67
El Salvador	-0.64	0.20	4.59
Sweden	1.07	0.17	0.73
Syrian Arab Republic	1.75	0.21	2.45
Togo	-0.49	0.22	7.10
Thailand	0.15	0.18	1.67
Tunisia	1.29	0.21	1.28
Turkey	1.23	0.18	1.81
Uganda	-0.27	0.24	6.01
Uruguay	-0.31	0.20	1.96
Venezuela	-0.16	0.19	3.27
South Africa	0.16	0.17	1.93
Zaire (DRC)	-0.57	0.22	4.32
Zambia	-1.05	0.23	3.90
Zimbabwe	0.14	0.19	3.55

Note: Technology parameters, λ_i, are recovered as detailed in section 4.2 and $\theta = 0.15$.